PB82-109588

Proceedings of the Conference on Innovation in the Environmental Technology Industry Held at Washington, DC, on November 5-6, 1980

Enviro Control, Inc.
Rockville, MD

Prepared for

Environmental Protection Agency
Washington, DC

Sep 81

U.S. Department of Commerce
National Technical Information Service
NTIS

EPA-600/9-81-030

Proceedings

PB82-109588

Conference on Innovation in the Environmental Technology Industry

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November 5-6, 1980
Capital Hilton Hotel
Washington, D.C.

Sponsored by:
U.S. Environmental Protection Agency
Water Pollution Control Federation
Air Pollution Control Association
Environmental Industry Council

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TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-600/9-81-030	2. Proceedings	3. RECIPIENT'S ACCESSION NO. PB82 109588
4. TITLE AND SUBTITLE Conference on Innovation in the Environmental Technology Industry		5. REPORT DATE September 1981
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) ENVIRO CONTROL, INC. , Editors		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS ENVIRO CONTROL, INC. One Central Plaza 11300 Rockville Pike Rockville, MD 20852		10. PROGRAM ELEMENT NO.
		11. CONTRACT/GRANT NO. 68-03-2674
12. SPONSORING AGENCY NAME AND ADDRESS U.S. Environmental Protection Agency Office of Research and Development Office of Environmental Engineering & Technology Washington, DC 20460		13. TYPE OF REPORT AND PERIOD COVERED
		14. SPONSORING AGENCY CODE EPA/ORD 17

15. SUPPLEMENTARY NOTES

16. ABSTRACT

This document comprises the proceedings of the Conference on Innovation in the Environmental Technology Industry, sponsored by the U.S. Environmental Protection Agency (EPA), the Water Pollution Control Federation (WPCF), the Air Pollution Control Association (APCA) and the Environmental Industry Council (EIC). The conference was held in Washington, DC, November 5-6, 1980.

More than forty conference papers are included, with a glossary of most acronyms appended at the end. Panel sessions and some of the papers are followed by brief questions from the floor and responses by the panelists or speakers. Major areas that were addressed included: assessment of pollution control technologies; venture capital constraints and considerations; impact of regulatory policies on new markets and development; Federal Patent Policy changes and impact on innovation; investment firms perspective for ventures and foreign technology exchange, sources, barriers and approaches.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group

18. DISTRIBUTION STATEMENT Release to Public	19. SECURITY CLASS *(This Report)* Unclassified	21.
A	20. SECURITY CLASS *(This page)* Unclassified	22. PRICE

EPA Form 2220-1 (Rev. 4-77) PREVIOUS EDITION IS OBSOLETE

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INTRODUCTION

The nation's pollution control industry is highly complex and sensitive, with a market that is not easily predictable. The industry is particularly sensitive to changes in EPA policies and regulatory actions. Recognizing this fact, we co-sponsored a conference on November 5-6, 1980 to provide a forum for discussing the key factors and issues influencing the development and marketing of innovative pollution control technologies.

The conference was unique in that for the first time it brought together government policymakers with experts in technology development, marketing, and financing to address the problems that the industry faces and to discuss possible ways to deal with these problems.

Based on the many responses we have received, we feel that the conference was highly successful in providing a whole new perspective on the promise and problems of bringing innovation to the pollution control industry. From our own perspective, the conference was immensely important. One direct result is that we are now considering the possibility of making our laboratories accessible to entrepreneurs and inventors with good ideas. We also have a much better understanding of the difficulties that the industry faces in attracting venture capital and in justifying resources for development projects. At the same time we hope that the industry has gained a better understanding of what we can do to help and what is beyond our control.

We are grateful to the Water Pollution Control Federation, the Air Pollution Control Association and the Environmental Industry Council for their encouragement and active support in co-sponsoring the conference and we are especially indebted to the many participants whose expertise and insight helped assure its success.

James V Basilico

James V. Basilico
Conference Technical Chairman
Office of Environmental Engineering
and Technology
Office of Research and Development
U.S. Environmental Protection Agency

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ABSTRACT

This document comprises the proceedings of the Conference on Innovation in the Environmental Technology Industry, sponsored by the U.S. Environmental Protection Agency (EPA), the Water Pollution Control Federation (WPCF), the Air Pollution Control Association (APCA), and the Environmental Industry Council (EIC). The conference was held in Washington, D. C., November 5 and 6, 1980.

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WELCOME AND CONFERENCE OBJECTIVES

Steven R. Reznek, Ph.D., Presiding Chairman
Deputy Assistant Administrator
Office of Environmental Engineering and Technology
U.S. Environmental Protection Agency

I would like to begin by explaining why we called this Conference and want to welcome all of you to a Conference on Innovation in what I call the Environmental Technology Industry.

The Conference is sponsored by the Water Pollution Control Federation (WPCF), the Air Pollution Control Association (APCA), and the Environmental Industrial Council. They are helping us bring the Conference to you today. I want to recognize Mr. Robert Perry of the Water Pollution Control Federation; Mr. Frank Partee, the past President; and Mr. Robert Eisenbach, the present President of APCA; and Mr. Arthur Mackwell, the current Chairman of the Environmental Industry Council for their help in cosponsoring and bringing the Conference to you.

What is the environmental engineering or environmental technology industry? It comprises those firms that make and sell pollution control equipment and the technologies that separate, stabilize, convert, or destroy waste materials.

The President's Council on Environmental Quality estimates that the 1978 expenditures for the whole country for pollution controls fostered by Federal regulations are just under $27 billion. Some fraction of this cost goes for the technologies, and the remainder is spent for fixed costs such as land, pipes, ducts, and construction.

The firms in the environmental engineering industry provide the products for this market. They create the solutions for our environmental problems.

How is the industry doing? How will it do in the future? Can it, in supplying its products, meet the challenges that our technological society faces over the next 20 years? Will cost-effective pollution controls be available to meet the needs of environmental protection while the United States faces its economic challenges of energy and mineral resource depletion?

The trade-off between environmental quality and industrial productivity is determined by the cost and the performance of pollution control technologies, the products of this industry. I would like to ask this question: Are these processes in place in our society today that will create the required innovations to enable us to achieve economic progress while not losing ground in protecting environmental quality?

This Conference was called to examine the processes that induce or inhibit innovation in environmental engineering products. One distinguishing aspect of the Conference is that it will ignore some of the differences in air pollution, industrial wastewater, municipal sewage, and hazardous waste disposal or treatment.

The Conference will, instead, focus on how resources are used in the private sector and perhaps also in the public sector to create new products, and how the new products are introduced into the markets. In this aspect the industry is unique--markets created principally by regulatory actions.

Pollution control manufacturers have in common a similar market situation with its own strange mixture of both public and private sector influences. Improved air, water, and solid waste technologies must all be sold to a customer who, to one degree or another, is being coerced into buying -- being coerced by Federal regulations, State regulations, or public pressures.

This situation has certain unique aspects, and, I hope, the Conference will examine how this situation affects the pace at which new products are developed and sold. The period between 1969 and 1972 saw the creation of the major Federal pollution control laws. During this period, Congress and the Administrations addressed the question of the rate of improvement of environment control technologies.

Prior to the legislation, the Federal Government heavily subsidized research, development, and demonstration of pollution control techniques. During the period of 1969 and 1972, this policy was substantially abandoned. The new legislation, the policies, and, most importantly, the Federal appropriations clearly stated that the private sector would create and sell its own improved technologies. The so-called racheting of "best-available" under the Water Act or "best-demonstrated" technology under the Air Act was supposed to provide the impetus for innovation. This so-called racheting of this technology operated under the following theory: Under the laws we created a large market, $27 billion per year; the large market created competition for profit; and competition was supposed to create the innovations. A legislative requirement for a five-year review of the technology-based regulation would redefine "best technology" based on the innovations that occur. It was a nice theory; unfortunately many people today doubt how well it has worked.

What do we really know about the process, and how well has it worked? The Department of Commerce and the Council of Environmental Quality document the size of the market. Some firms--for example, Arthur D. Little--have published various prospecti on parts of the market--for example, instrumentation of flue gas desulfurization.

EPA has done a few studies to look at the growth and the profits in the industry. We have also looked at the need and the sources of supply for capital for the industry. We have also done some post mortems, that is, some investigations into some of the unsuccessful ventures: Union Carbide's wet oxidation; Monsanto's and some of Dow's experiences.

The National Science Foundation tries to measure the research and development investment in environmental engineering. Beyond these few efforts we know very little. We do know that there are signs of stress in the industry.

For the next two days we will examine the question of innovation. In today's session we will address or assess what is happening in air and water pollution control, and in hazardous waste incineration.

Tomorrow we will leave the engineering area and look at some of the areas where innovation has occurred, and we will try to understand what forces were at work to produce that innovation. We will look also at certain areas where innovation did not work and will try to understand what went wrong.

Obviously, the political context of the environmental legislation is changing. However, the fundamental need to preserve environmental quality certainly continues, and the popular acceptance of stringent pollution controls continues to be documented in every poll, be it taken in industry, by the Government, or by public interest groups.

Attendees at this Conference have demonstrated a commitment to participation in the environmental engineering industry, and I continue to believe that the industry will remain strong. The Conference attendance comprises about 31 percent of people in research; 10 percent in financial policies and marketing; 18 percent in consulting; 18 percent in major corporate planning--the people who decided where the research and development (R&D) investment is going to go; and about 23 percent in other fields.

I hope each of you finds the Conference interesting and stimulating and comes away with new information and a new perspective on our mutual industry.

Thank you.

Keynote Address

Douglas M. Costle, J.D.
Administrator
U.S. Environmental Protection Agency

KEYNOTE ADDRESS

Douglas M. Costle, J.D.
Administrator
U.S. Environmental Protection Agency

As recently as 1977, A. D. Little estimated that the annual revenues of the pollution control industry stood at about $1.8 billion and projected them to increase to $3.5 billion by 1983. By any normal definition that would qualify your industry as a growth enterprise.

Yet, as you are aware, there are clear signs of distress in the industry today. Some industry leaders, Union Carbide, Monsanto, Dow, Enviro-Tech, for example, are either reducing their efforts or backing out entirely from pollution control. Peabody International has spun its environmental section off from its energy activities so that the two will proceed as financially autonomous operations.

Just last month Combustion Equipment Associates filed for a protection under Chapter XI. Thus, your industry represents a seeming paradox -- some notable financial defeats in the midst of a growing and, I think, undeniably permanent market.

In view of the Government's prominent role in your industry, it is clearly pertinent to ask whether the Government is not at least partly responsible for the problems you now face and I am forced to concede that it is. Some of these problems the EPA can probably do something about. Some of them, while we can urge changes, lie outside our jurisdiction.

Today I will try to sort out some of these and indicate where I think we should be helping.

The most common complaint about the Government's role in the pollution control industry is uncertainty. How stringent are environmental regulations going to be? When will they be passed? How long will they be held up by litigation? And how tough will their enforcement be?

The answers to most of these questions, regretfully, are beyond EPA's control. In view of constant criticism about Government red tape, it is worth noting that a substantial amount of the uncertainty and delay in environmental regulation is created by the legal red tape of a corporate variety.

In the course of our tortured efforts, for example, to develop the regulations required by Congress for the Resource Conservation and Recovery Act, we received 4,000 separate and individual comments. Stacked on a shelf, these comments measured 8 linear feet. And we are required to respond to all of those comments and explain, in writing, why we chose to adopt some and not others.

There are, as well, other causes of uncertainty that complicate investment decisions and inhibit innovation. The lengthy evaluation of bids on treatment plants -- bidding procedures that prohibit the specification of proprietary equipment and hence make companies reluctant to invest in research and development -- and post-bid shopping which can reduce honest profit margins or lead to substitution of inferior equipment.

To repeat, some of these problems are beyond our control but others are not. In the last two years or so we have been looking at our regulations, trying to find ways to stimulate innovation and control pollution at a lower cost.

Some of these ways are well known by now. Our bubble policy, for example, permits managers to treat plants as a single emission system rather than as dozens or hundreds of point sources, each of which must be controlled through a rigid standard. By allowing managers to tighten up on easily controlled sources, the bubble permits the same or even better plant life control for less cost.

Similarly the so-called offset policy stimulates the search for stringent pollution control measures to permit industrial expansion in air sheds that could not otherwise approve new development. The emissions banking system would reward companies that exceed pollution control requirements by allowing them to retain, trade, or even sell their surplus.

All of these methods, collectively known as controlled trading, are efforts to supplement Government regulation with free market forces and stimulate the search for innovative, more cost-effective cleanup methods.

In addition, we are examining our programs in three other areas for their effect on the pace of innovation in the pollution control industry. These areas include Federal patent policies, the use of innovative waivers, and permitting environmentally advantageous technologies in the innovative and alternative technology setaside in the construction grants program.

At present, EPA has taken the traditional view that technological innovations developed through federally subsidized research are in the public sector. In a recent message on innovation, President Carter announced that he would seek legislation to change this policy. We continue to think that such legislation would be desirable. I think a new Administration coming in would agree.

Though the Government would retain title to the patent, it could grant the contractor exclusive licenses in fields of use that he specifies and in which he agrees to commercialize the invention. In the meantime, EPA can assign patent to a research contractor, as we have done in a very few instances. Because such waivers can speed the commercial use of inventions that would otherwise sit on the shelf, I think EPA needs to concentrate on improving its record. We encourage contractors to apply for such waivers.

As you know, a few provisions of the Clean Air and Water Acts allow companies to delay compliance if they are experimenting with a new technology. We are not satisfied, quite frankly, with the effectiveness of those provisions as they now stand. For one thing, the Act requires compliance at the end of four or eight years, a period that is generally too short to allow significant depreciation of capital.

For another, the wording of the innovation waiver creates a kind of Catch-22 situation. Under that wording an innovation waiver may be granted if EPA judges that two conditions exist. First, that an experimental method offers substantial promise of increasing levels of control or reducing cost and, second, that the method genuinely qualifies as innovative.

Taken together, these two conditions demand a judgment of EPA. Interpreting them with customary bureaucratic caution, EPA officials have tended to conclude that unless a given method has been proven to work, there is no reliable evidence that it will. And if there is evidence to prove it will work, is it innovative?

Whatever this procedure does to shield government officials from criticism, it clearly does nothing for innovation, and consequently we are examining the language of the innovation waiver provisions with a view toward recommending legislative changes. These changes might also include extending the time period and reducing a company's financial jeopardy if its good-faith efforts in the experimental technology failed; particularly, if the company fails to achieve, in a bottom line technical sense, compliance.

We are, in addition, examining EPA's procurement regulations and State review procedures for the Waste Water Construction Grants Program. I think that the flexibility of the application and review procedures has been improved in the last couple of years; but even so, a great deal of streamlining remains to be done, and we are giving particular attention to improving provisions regarding the 2-percent setaside for innovative and alternative wastewater treatment systems.

Finally, I think that the pollution control industry has suffered in the past from a lack of cooperation with EPA. In the early days of my service with the Agency, we were approached by a representative of an industry with a request for such cooperation. That request in that instance took a form which I considered to be inappropriate, that is, the endorsement of specific products after we had evaluated them.

I still consider this inappropriate and I feel, moreover, that any government that combines grant awarding and regulatory functions must maintain a prudent distance between itself and its contractors. Nevertheless, I can concede to you today that we erred on the side of excessive caution in that matter and that our prudent distance widened into a gulf.

This needs to be remedied -- and that is one of the principal reasons for joining in the sponsorship of this Conference. Further, our intention to develop a productive partnership should not evaporate as soon as this Conference adjourns. On the contrary -- and I know the professional staff at EPA feels quite sincerely about this -- we want to explore with you a proper role for EPA in making sure that the vital causes of environmental protection will be advanced by a healthy and profitable pollution industry.

Let me close with a few observations that I think set the context for the future of this industry:

First of all, despite the hardships and frustrations you have experienced, I think the industry is here to stay. Public opinion polls in the last few years have been unanimous in reporting that the American people feel that there is too much Government regulation in their lives. But those same polls have been equally unanimous in reporting that when asked about specific types of regulation, large majorities believe environmental regulation should be kept at least as strict as it is, or even made more so. Respondents hold these views even though they acknowledge that such regulations raise prices.

Second, I suspect your industry will undergo an evolution similar to the one that has taken place in the computer industry. When electronic data processing was commercially introduced in this country, the industry's emphasis was obviously on selling hardware. Software was often given away. Today, with the sharp drop in the hardware cost of computers as a function of processing capability, coupled with the need for specialized industry applications, the market has begun shifting towards software -- programs.

In an analogous way I think the pollution control market will shift away from hardware to "word process" change, that is, in essence, devising ways to prevent pollution from being generated in the first place, rather than designing black boxes to capture waste after the fact. This does not mean that all pollution control hardware will disappear any more than computers have disappeared or will do so. But it does reflect the fact that our manufacturing and industrial processes have been designed around cheap energy, low-priced water, free air, and inexpensive, virtually inexhaustable supplies of raw materials.

Today none of these assumptions necessarily hold. We are forced, I think, to reshape our industries in the context of today's world to correspond with the reality of resource limitations. Instead of conflicting with the necessity to reindustrialize our country and boost productivity, this equal need to reshape the American economy around new environmental assumptions will assist our drive toward economic recovery.

Finally, it is not public opinion polls alone, I think, that guarantee the future of pollution control, conservation, and the wise use of materials as an integral part of economic advance. Rather, it is a set of four intersecting phenomena that I think have profoundly altered our lives and our world within the last generation and will, perhaps, even more profoundly alter our lives in the future.

First, population growth. From the time of human emergence on the globe, about 3 million years ago, population numbers did not reach 1 billion until 1830 A.D. By contrast, between 1960 and 1975, we went from 3 billion to 4 billion. This addition to human population that once required 3 million years has been telescoped in our lifetimes to a mere 15 years. By the turn of the century, despite our recent progress in population control, this period will be further reduced to only 9 years.

Second, synthetic compounds. Until the 1930's, most substances used by people were compounds of natural materials, principally minerals and plants. Since the 1940's, however, our chemical industry has given us an astounding number of synthetics, some of them utterly alien to our planet and its natural filtering processes.

Today 5 million chemicals are known to exist, more than 50,000 of which are in commercial distribution. It takes a team of pathologists, 300 test animals, 2 to 3 years, and about half a million dollars to determine whether a single one of these chemicals causes cancer.

Third, the scope of our technology. The scope of our technology has been magnified beyond any dreams of medieval thought. In 1945, for example, the largest oil tankers had a capacity of about 18,000 tons. In 1978, by contrast, the Amoco-Cadiz alone dumped 220,000 tons of oil (the equivalent of a dozen prewar carriers) off the coast of Brittany.

Who in 1945 could have guessed that millions of human beings spraying deodorants in their bathrooms might erode the ozone shield? Who in 1950 could have guessed that sulfur and nitrogen oxides rising from one nation might fall on another as acid rain, slowing forest growth and impoverishing forests or killing lakes?

In the broader social and political sphere, who in 1960 could have predicted that nations would quarrel furiously over rights to mineral deposits on the ocean floors or invisible communication channels in the skies?

Human aspiration for a better life is not going to change. And we have developing nations around this world who aspire to a life as productive in a quantitative sense, by quantified measures, as we have and enjoy now.

Fourth, we are dealing with accelerated pace -- the astonishingly brief span, on the order of 35 years, in which so many novel and even massive changes have been introduced to our 5-billion-year-old habitat. Had they occurred separately or been spread out over centuries such changes could have and for the most part have, until now, been accommodated through natural evolution and human adaptation. But coming both swiftly and simultaneously, these changes magnify each other's impact in an often profound synergism.

These four issues, I think, and the regulations that they trigger -- our efforts to find new rules to govern ourselves by -- have not been brought to us by a big government that is eager to aggrandize itself. They have, on the contrary, been brought to us by a big society, one whose incredible cleverness is catching up with the globe's finite capacity to sustain us.

We must wonder, to adapt Robert Browning's phrase, whether our technological reach exceeds our intellectual grasp. Restoring equity between these two, between our ingenuity and our wisdom, is the business that we are all about. Considering the brief period of time that we have been on the job and the brief period of time in which your industry has existed, we have done a great deal of work. We should not overlook that. But I hope that I and future administrators of EPA can in fact count on your help in meeting the mandate that has been imposed on us by our fellow citizens and that I don't think, in all sincerity, will be undone.

I know that the folks of EPA are 10 years wiser just as you are 10 years wiser and that there is, in fact -- again irrespective of Administration -- a growing spirit and sense of the need to work together and find ways to make both our paths smoother in the future.

Thank you very much. I hope that you will have a good Conference.

Session I
Technology Assessments

Presiding Chairman:
Steven R. Reznek, Ph.D.
Deputy Assistant Administrator
Office of Environmental Engineering and Technology
U.S. Environmental Protection Agency

Air Pollution Control Technology

Chairman:
Frank Princiotta
Director, Industrial Environmental
Research Laboratory
U.S. Environmental Protection Agency

Panelists:
Charles R. LaMantia
Grady B. Nichols
Martin F. Collins
Victor H. Sussman

AIR POLLUTION CONTROL TECHNOLOGY - SELECTED EPA-SPONSORED PROGRAMS

Frank T. Princiotta, Director
Industrial Environmental Research Laboratory
U.S. Environmental Protection Agency

There are many exciting developments in the area of air pollution control technology. Our panelists will discuss some of these in subsequent papers, but I would like to highlight three promising technologies being developed through EPA's research program. In addition to describing the technological status and potential of these technologies, I believe this discussion will illustrate the role federally-sponsored research can play in promoting innovative control technology. The three technologies that I will include are:

- Adipic acid augmentation of lime/limestone scrubbing for improved sulfur oxide control
- Pulverized coal multistage burners specially designed for low nitrogen oxide emissions (low NO_x burners)
- Limestone injection in the multistage burner (LIMB) for both sulfur oxide and nitrogen oxide control.

Adipic Acid for Enhanced Sulfur Oxide Control

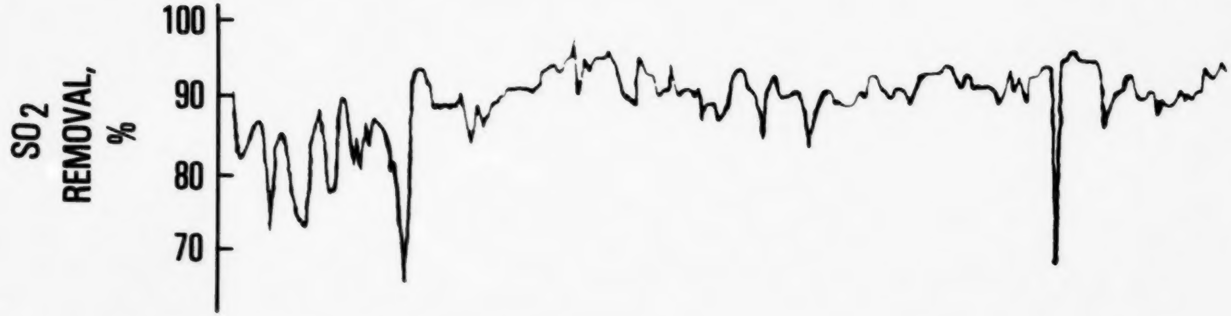
The EPA and DOE are investigating the use of additives to lower the costs and improve the performance of lime/limestone flue gas desulfurization systems. We have evaluated the use of magnesium oxide, adipic acid, and formic acid. A magnesium oxide additive will improve the performance of lime/limestone desulfurization processes. Magnesium oxide is used at the Bruce Mansfield Station of Pennsylvania Power Company. However, the use of magnesium oxide is limited by the characteristics of the coal.

EPA initiated research and development to identify alternative agents which would promote the performance of lime/limestone desulfurization systems. We are testing the most promising additive - adipic acid - on a 10-megawatt prototype scrubber at TVA's Shawnee Steam Station. Table 1 presents the effect of adipic acid on the performance of a limestone system treating the flue gas from a 3.5 percent sulfur coal. At adipic acid concentrations in the range of 700 to 1,500 ppm, SO_2 removals consistently exceed 90 percent. SO_2 removals are effectively enhanced, even when operating on coals which contained contaminants that limit the effectiveness of other additives. Figure 1 depicts the dramatic improvement in SO_2 removal efficiency as well as the dampening effect observed during Shawnee testing.

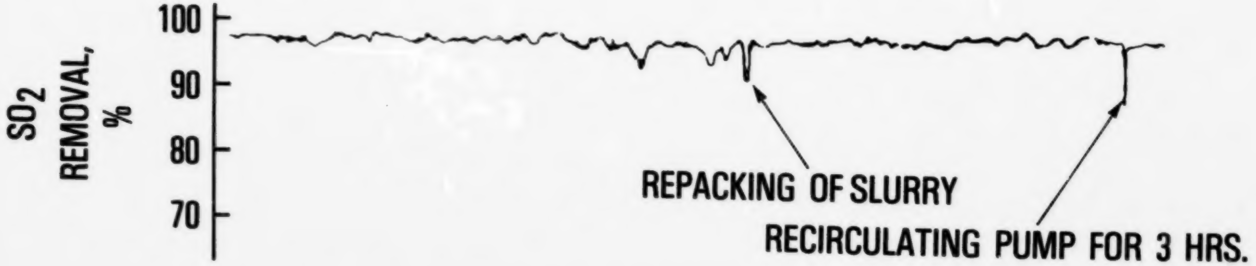
The projected costs of adipic acid additives for lime and limestone scrubbing systems are favorable. Both capital and operating costs are reduced by about 5 to 7 percent for systems designed to remove 90 percent of the incoming SO_2. This amounts to a \$6 million capital cost savings for a typical high sulfur coal-fired, 500 MWe flue gas desulfurization system.

Figure 1

IMPACT OF ADIPIC ACID ON SCRUBBER PERFORMANCE



LIMESTONE/NO ADIPIC ACID



LIMESTONE/ADIPIC ACID ADDITION

Table 1
Effects of Adipic Acid on Sulfur Oxide Removal

Concentration of Adipic Acid In Scrubber Liquor, PPM	Percent SO_2 Reduction
0	71
350	75
885	92
1,600	93

EPA and DOE are currently sponsoring the full-scale demonstration of adipic acid modified limestone wet scrubbing on a 194 MWe boiler in the Springfield City Utility network. Testing of the system began September 5, 1980, and has proceeded without problems. The preliminary performance of the system was improved from 65 to 75 percent SO_2 reduction to 92 to 93 percent SO_2 reduction when 1,000 ppm adipic acid was added to the scrubber liquor. We are planning to operate this site for six months to demonstrate the long-term reliability of adipic acid modified limestone wet scrubbing.

Low NO_x Burners

Nitrogen oxide in flue gas results mainly from the burning of organic nitrogen in coal. EPA developed a staged combustion burner that minimizes nitrogen oxide formation by reducing the peak temperatures and the available oxygen in the hottest part of the flame. The multistage burner is only applicable to wall-fired boilers, which represent about 45 percent of utility steam capacity in the United States. Tangentially-fired boilers account for approximately another 45 percent of utility steam capacity. Although tangentially-fired burners are inherently low-NO_x emitters, a staged combustion approach, the so-called rich fireball concept, has been developed to reduce NO_x emissions even further. In the rich fireball burner, the air injection pattern allows the center of the fireball to maintain a low air/fuel ratio. This oxygen deficiency minimizes NO_x formation.

The multistage burner for wall-fired boilers was developed by the Energy and Environmental Research Corporation under EPA sponsorship. This burner has been tested at a large pilot plant (120×10^6 BTU/Hr). Contracts have been awarded to perform full-scale field evaluations of the burner at two industrial boilers (100 to 500×10^6 BTU/Hr) and one utility boiler (300 MWe). Parallel development work is being performed by Steinmuller in the German Federal Republic. Figure 2 depicts the operation of this burner.

EPA has also sponsored the development of the rich fireball burner for tangentially-fired boilers. This system has been tested at a small pilot scale (1×10^6 BTU/Hr). Private test work has also been performed by Combustion Engineering, sole manufacturer of tangentially-fired boilers in the United States. EPA and Combustion Engineering plan to cooperate on a full-scale utility test program on a 400 MWe utility boiler. Figure 3 shows a schematic of the rich fireball concept.

FIGURE 2 MULTI-STAGE COMBUSTION IN EPA'S LOW NO_X BURNER

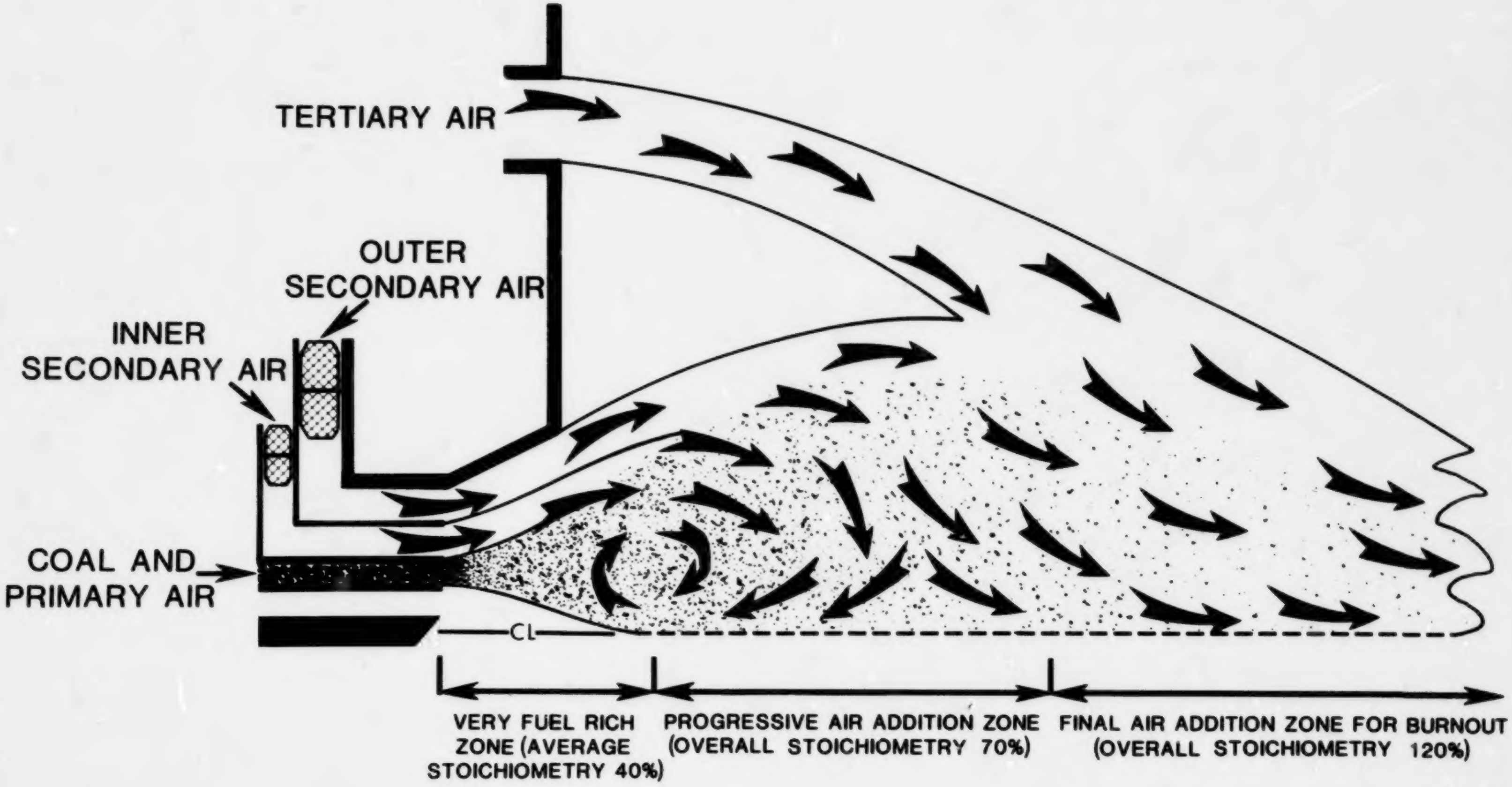
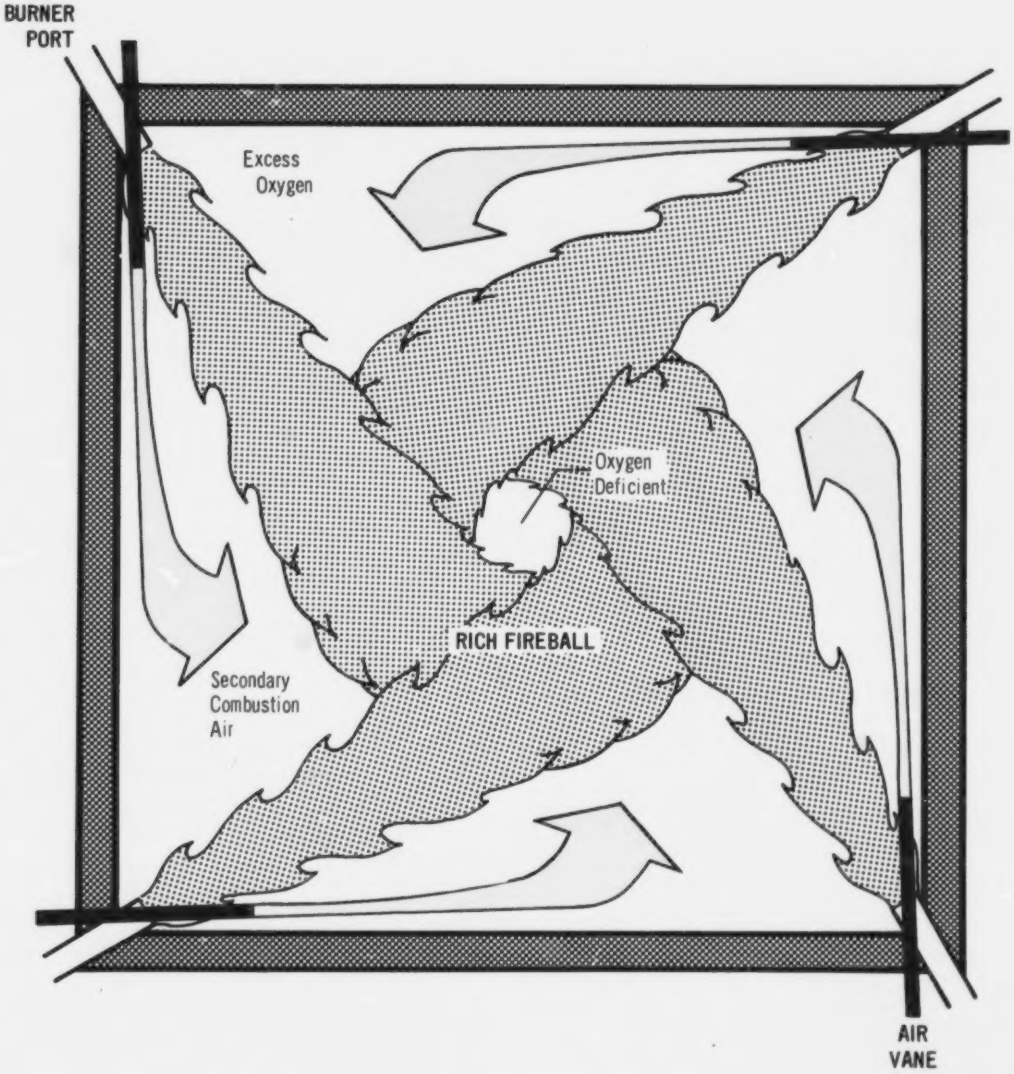

TERTIARY AIR
OUTER SECONDARY AIR
INNER SECONDARY AIR
COAL AND PRIMARY AIR
CL
VERY FUEL RICH ZONE (AVERAGE STOICHIOMETRY 40%)
PROGRESSIVE AIR ADDITION ZONE (OVERALL STOICHIOMETRY 70%)
FINAL AIR ADDITION ZONE FOR BURNOUT (OVERALL STOICHIOMETRY 120%)

FIGURE 3

TANGENTIALLY-FIRED RICH FIREBALL (LOW NOx) BURNER

PLAN VIEW


BURNER PORT
Excess Oxygen
Oxygen Deficient
RICH FIREBALL
Secondary Combustion Air
AIR VANE

Neither the multistage or rich fireball burner is considered to be a proven technology at the present time. The proven state-of-the-art is overfire air for tangentially-fired boilers and dual register or dual throat burners for wall-fired boilers. Current state-of-the-art can achieve NO_x emissions of approximately 0.5 pounds per million BTU. The current utility NO_x emissions standard is 0.5 lb /MM BTU (215 ng/J) for subbituminous coal and 0.6 lb /MM BTU (258 ng/J) for bituminous coal.

Pilot plant test results have shown that NO_x emissions of 0.2 to 0.3 lb/ MM BTU (86 to 129 ng/J) can be achieved with both multistage and rich fireball burners. No adverse boiler side effects have been observed during testing. The field evaluations will establish the emissions level that can be achieved under prolonged operating conditions. The field tests will also be monitored to confirm that the low NO_x burners will not cause any slagging, corrosion, or incomplete combustion problems.

The multistage and rich fireball burners are extremely inexpensive to install and operate. The initial costs for new and retrofit installations for multistage burners are $5 to $10 per kilowatt and for rich fireball burners are $1 to $3 per kilowatt. There are virtually no operating expenses.

The annual revenue requirement for low NO_x burners is only 0.2 to 0.4 mills/KwHr. This compares favorably to annual revenue requirements of 0.7 to 1.1 mills/KwHr for thermal noncatalytic ammonia injection and 4.5 to 5.8 mills/KwHr for selective catalytic reduction (SCR). The low NO_x burner operates at a cost of under $100/ton of NO_x removed, compared to over $300/ton and $1,200/ton for thermal and catalytic denitrification.

The LIMB Program

I would now like to turn to the question of pollution controls for existing sources. Many older combustion sources could not be modified to use pollution control technologies or would not be able to afford to depreciate capital costs over the remaining lifetime of the facilities. EPA and DOE are examining low-cost alternatives to reduce the emissions from these facilities. One innovative sulfur oxide control process is the limestone injection into multistage burners (LIMB) process. The LIMB process is an adaptation of the low NO_x burner to provide simultaneous control of NO_x and SO_x emissions. The process employs dry limestone injection into the boiler along with the pulverized coal. The heat of combustion calcines the limestone to lime, and the lime reacts with the SO_2 released by coal combustion to form calcium sulfite and calcium sulfate. The dry reaction products are collected along with unreacted reagent and fly ash downstream of the air preheater. Based upon preliminary data, we project that the LIMB process would be capable of reducing SO_2 emissions by 50 to 80 percent.

The idea of dry direct limestone injection into a furnace to control SO_2 emissions is not new. Researchers in Germany, Japan, Poland, Czechoslovakia, and the United States experimented with dry sorbent injection throughout the 1960's and early 1970's. Bench, pilot, and full-scale tests were performed utilizing limestone, dolomite, and hydrated lime in conventional boiler designs. The results of these early test programs were not encouraging. Removal percentages did not exceed 40 percent and limestone utilization did not exceed 20 percent. However, recent tests on burners (or boilers) staged for low NO_x operation have been encouraging. Figure 4 plots available data for both conventional and low NO_x burners. The data suggests that our goals of 50 to 80 percent removal at resonsable limestone feed rates (stoichiometry) is achievable. We believe low NO_x burners create the flame conditions (temperature and chemistry) necessary for effective sulfur oxide removal.

The simplicity of the LIMB process (Figure 5) means low initial capital investment for retrofit applications. The capital cost components of the LIMB process include limestone storage and handling facilities, multistage burners, increased particulate removal capability, and added waste disposal facilities. The total capital investment is estimated to be $15-34/Kw and the total annual revenue requirement is estimated to be 2.9-3.6 mills/KwHr.

Observations on the Federal Role

I believe these three programs suggest that the Federal government can and should play a major role in environmental control technology innovation. It seems to me, however, that Federal research can only be justified when the private sector is either unwilling or unable to do the job. I suggest that at least one of the following questions must be answered affirmatively for Government-sponsored research to be appropriate:

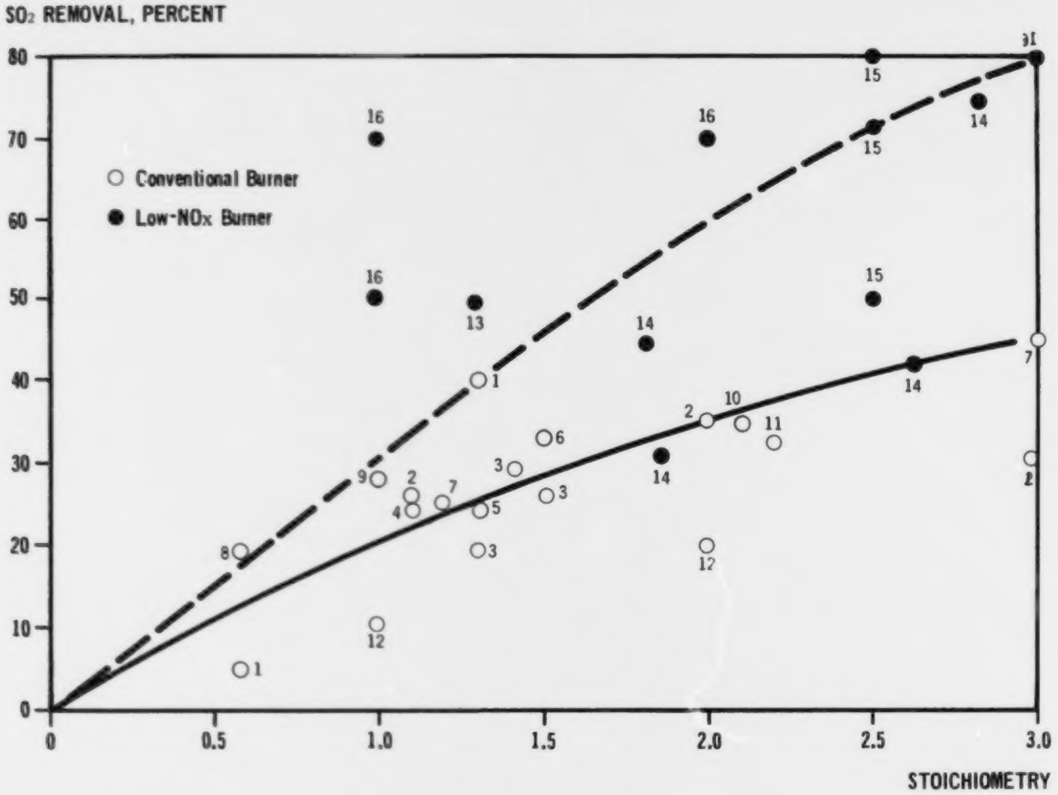
- If successful, will the taxpayer have made a prudent investment considering the potential pollution control compared to the cost?
- Does the private sector have insufficient financial incentive to invest in innovative technology?
- Does the research involve resource requirements - dollars, manpower, or hardware - above and beyond that which the private sector can afford?

My analysis of the programs described is that the answers are 'yes' for all questions for all three technologies. For all three technologies, a successful research program could allow for important regulation changes. For example, successful demonstration of the low NO_x burners could allow for the setting of more stringent New Source Performance Standards (NSPS) for both utility and industrial boilers.

Clearly, it is unreasonable to assume that the Agency's desire to tighten a currently weak NSPS should motivate the private sector to invest scarce research resources to push the state-of-the-art of low NO_x combustors. This is especially so since such burners could lead to somewhat more expensive, complex, and perhaps even less reliable products. Similar arguments can be made about industry's incentive to enhance the efficiency of limestone scrubbing through adipic acid addition or to develop the LIMB technology applicable primarily for acid rain control for which there are no current regulations.

FIGURE 4

SO2 REMOVAL vs. STOICHIOMETRY FOR REPORTED PLANT-SCALE TESTS OF DRY LIMESTONE INJECTION PROCESS

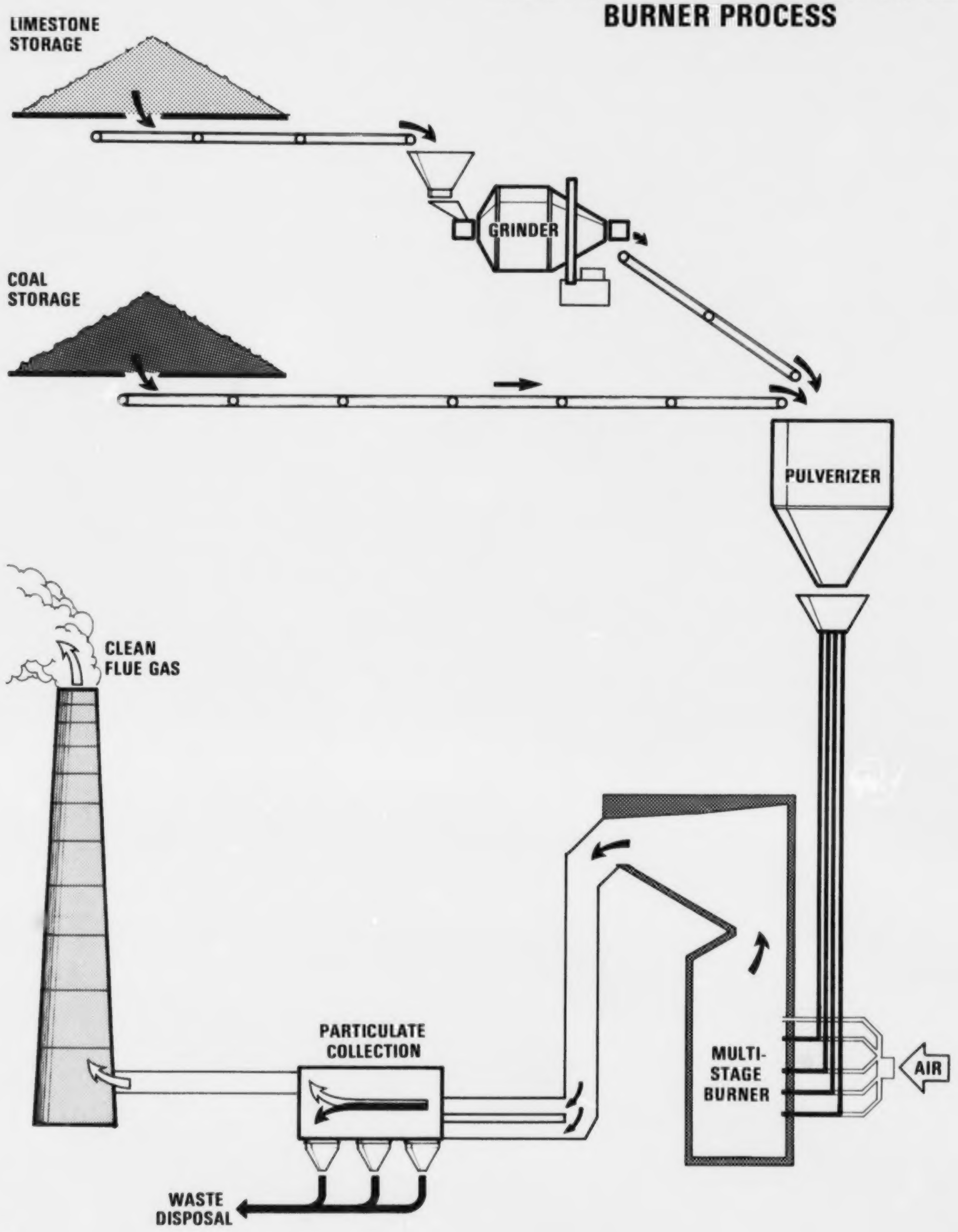


KEY	INVESTIGATOR	FUEL	SORBENT
1	Wisconsin Electric Co.	Coal	Ground Dolomite
2	Detroit Edison Co.	Coal	Ground Dolomite
3	Steag (W. Germany)	Coal	Ground Limestone
4	Kansas Power & Light (CGE, Inc.)	Coal	Limestone
5	Union Electric Co (CGE, Inc)	Coal	Dolomite
6	Energopomiar (Poland)	Coal & Gas	Dolomite
7	Central Research Institute of Electric Power (Japan)	Oil	Limestone
8	Republic Coal & Coke	Coal	Dolomite

KEY	INVESTIGATOR	FUEL	SORBENT
9	Republic Coal & Coke	Coal	Dolomite
10	General Motors	Coal	Dolomite
11	General Motors	Coal	Limestone
12	Tennessee Valley Authority	Coal	Limestone
13	UOP	Coal (Arch-Fired)	Limestone
14	RWE (W. Germany)	Coal	Limestone
15	Steinmüller (W. Germany)	Doped Gas	Limestone
16	EERC	Coal	Limestone

Source: TVA, 1973.

FIGURE 5
SCHEMATIC FLOW DIAGRAM OF THF LIMESTONE INJECTION/MULTI-STAGE BURNER PROCESS


LIMESTONE STORAGE
GRINDER
COAL STORAGE
PULVERIZER
CLEAN FLUE GAS
PARTICULATE COLLECTION
MULTI-STAGE BURNER
AIR
WASTE DISPOSAL

It is also my impression that each of these projects would strain the research resources of the major vendors. Although I have not read a definitive paper on this subject, I believe that most research budgets for the major air pollution control vendors are less than $1 million annually. Since all three projects involve full-scale testing, which involves resource requirements in excess of this figure, I believe it unlikely that such projects, at their current scale, would likely be funded privately even assuming a reasonable financial incentive.

FLUE GAS DESULFURIZATION - NEW AND EMERGING PROCESSES

Charles R. LaMantia
Vice President
Arthur D. Little, Inc.

Last week in Houston, there was a four-day symposium sponsored by the U.S. Environmental Protection Agency (EPA) on the subject of Flue Gas Desulfurization (FGD). About 800 people attended and about 50 papers were presented. Interest remains very high, as does the level of activity in this area of technology. In this paper I will attempt to summarize briefly the essence of that four-day symposium.

THE MARKET

Any such summary should include a description of the marketplace for FGD technology--a very specific market that consists primarily of providing flue gas desulfurization systems for new, coal-fired utility boilers.

The market projection for the next ten years is on the order of 10,000 megawatts per year of new coal-fired utility capacity. A few years ago this market was projected to be multiples of this number. There has been an obvious drop in the growth in demand for electricity down from levels of 7% expected in the mid-70's to current projected levels of 2-3% or possibly less. There will continue to be delays in new construction and cancellation of new capacity; and this 10,000 megawatt per year figure may actually turn out to be somewhat optimistic.

FGD system costs are in the range of $100-$200 per kilowatt for new coal-fired boilers, depending upon the application and owner's costs, such as interest during construction, which are usually included in reported system costs. Taking half the system cost as potentially available for contract award to system suppliers, a market in the range of $500 million to $1 billion a year may result from the 10,000 megawatt per year of new applications. This market still holds interest for system suppliers, although it appears to be considerably smaller than projected earlier.

In addition to new coal-fired boilers, conversion of oil-fired units, which once were capable of burning coal, back to coal, may represent another large market for flue gas desulfurization. However, the Federal government has been trying to prod the utility industry into converting coal-capable boilers back to coal since the mid-1970's. Only two systems are currently being converted back to coal; neither of these reconversions will include installation of an FGD system. Conversions back to coal, to the extent that they occur, will probably not represent an important market for FGD systems.

Regarding industrial boilers, EPA is scheduled to propose new source performance standards in December, 1980, with possible promulgation in 1981. These standards will probably cover a wider range of sizes for new industrial boilers and should increase FGD applications on these smaller size boilers. There are currently several FGD systems in operation on industrial boilers. These systems typically are simpler and involve higher chemical and operating costs than systems applied to utility boilers. The somewhat simpler technologies are offered by a different set of competitors than normally participate in the utility market.

Returning to the utility market, there are roughly a dozen suppliers of FGD systems for large coal-fired utility boilers. The number of suppliers is increasing in spite of the fact that market projections are decreasing. There are new entries into the market: European companies, Japanese companies and U.S. companies acquiring licenses to technologies offered by overseas companies.

There are new technologies available, the principal one being a dry scrubbing approach which I will describe later. There are currently ten companies active in dry scrubbing; six of these are new entries into the flue gas desulfurization market; six did not, prior to dry scrubbing technology, offer a wet scrubbing system in this market.

The FGD system market has always been highly competitive and perhaps is becoming more so. If we consider 10,000 megawatts per year and an average unit size of 500 megawatts, we have roughly 20 new units per year. Some units are larger and some would be multiple awards. Given the number of awards and the number of competitors, we can expect fewer awards per year than there are system suppliers.

Awards are generally made on the basis of lowest evaluated cost to do the job reliably. So, the pressure is on the suppliers to come up with cost-effective technology, new technology, and technology improvements that are going to give required performance at minimum evaluated cost.

What might those new technologies and improvements be?

TECHNOLOGY TRENDS

The technology is generally considered in two categories:

1. The nonrecovery processes--these are processes that produce a waste solid or gypsum generally considered to be for disposal as opposed to sale; and

2. The recovery processes--these produce a byproduct sulfur value, usually elemental sulfur, and possibly sulfuric acid if a local market exists.

For nonrecovery processes, the trend is to use limestone rather than lime for significant system operating cost reductions. In terms of waste disposal, the EPA is looking very carefully now at the characteristics of fly ash and FGD wastes and the methods of disposal of these materials at coal-fired utility plants. It is unlikely that these materials will turn out to be hazardous. Close investigation, however, may result in more standardization of waste disposal practices and provide incentive for FGD system suppliers to offer systems that generate a much more easily disposable waste. Systems that produce gypsum as a waste product, to reduce disposal costs and other disposal problems, will receive broader application in the industry. Other improvements in recovery systems include absorption system designs to improve SO_2 removal, and to incrementally reduce capital investment.

For recovery systems, most of the developmental efforts are going into systems that will use coal as a reductant to reduce sulfur dioxide to elemental sulfur. Technology using hydrogen and methane for recovery of elemental sulfur has been proven but not widely applied because of costs or because of unavailability of natural gas for utility applications. Use of coal as the reductant should reduce costs and circumvent the gas availability problem.

In the past,well over 90% of the systems that have been commercially bid and applied in the utility industry have been of the nonrecovery process type. These processes are simpler and less expensive. The utility industry has much more experience with those systems than with the recovery systems. I would expect this trend for strong preference of nonrecovery systems to continue over the next decade in spite of attempts to develop more cost-competitive recovery processes.

Regarding the costs of nonrecovery processes, I believe the costs have peaked in real terms. The problems appear basically to have been solved and further technology improvements or new technology actually should reduce costs (in constant dollar terms and assuming no further tightening of regulatory requirements for performance improvements).

NONRECOVERY PROCESS DEVELOPMENTS

Some of the continuing work to improve this technology was described by a previous speaker, Frank Princiotta, of the EPA. He described work on forced oxidation to produce gypsum as a waste product in the limestone scrubbing process. Important work was done on this process by the U.S. EPA and the Tennessee Valley Authority (TVA). Both of these organizations also have worked on development of the use of adipic acid in limestone scrubbing to increase sulfur dioxide removal efficiency. In limestone scrubbing systems, the adipic acid approach is compatible with forced oxidation.

Some work has been done at TVA on high velocity, concurrent scrubber designs. Such scrubbers should be smaller and more compact, reducing system capital costs. The approach is somewhat similar to a Japanese technology developed by Mitsubishi and now licensed in this country to Badger, another new entry into the flue gas desulfurization market.

Chiyoda has been active in the United States for several years but has not yet sold a full-scale system. Chiyoda has developed a new process which was tested in a 20-megawatt prototype with the support of Electric Power Research Institute (EPRI). The process uses limestone and incorporates forced oxidation to produce gypsum. The process was reported to have an SO_2 removal capability well in excess of 90% with good reliability and good limestone utilization. Support of a larger demonstration for this process is likely.

There are two lime based dual alkali systems in full-scale utility applications on high sulfur coals; both of these have demonstrated very good SO_2 removal, well in excess of 90%, and good reliability. A possible constraint on further application of this process is the cost of lime versus limestone. The EPA is sponsoring some prototype work on limestone in a sodium based dual alkali system. TVA has done some work on the Dowa process, which uses limestone in an aluminum based scrubbing process to produce gypsum. These approaches would extend dual alkali technology to the use of limestone, improving its cost competitiveness relative to direct limestone scrubbing.

The last category of new nonrecovery process technology is dry scrubbing using lime, sodium carbonate, or some other form of sodium salt. A solution or slurry of the alkali contacts the flue gas in a spray dryer where absorption of SO_2 occurs. The water evaporates to produce a dry salt for collection, along with the fly ash, in a fabric filter or electrostatic precipitator following the spray dryer. Twelve contracts have been let for dry scrubbing systems in full-scale utility applications. All are for low sulfur coal. None of the systems are operational yet. The first full-scale utility startup is scheduled for about mid-1981, although there is a 100-megawatt demonstration facility which should be operating soon.

There are two industrial systems on medium sulfur coal using dry scrubbing and considerable pilot plant background work for the process. The industry is optimistic about the application of this technology to low sulfur coal. The approach is simple and promises lower costs, roughly 10-20% lower than comparable wet scrubbing approaches.

There is some question regarding the applicability of this technology to high sulfur coals. Is the process capable of 90% SO_2 removal for high sulfur coals? If yes, then how do the economics of dry scrubbing with lime compare with wet scrubbing with limestone? The developers of this technology and the system suppliers are optimistic about the eventual extension of this approach to high sulfur coals.

RECOVERY PROCESS DEVELOPMENTS

In the recovery process area, there are a few important programs under way. One is the Aqueous Carbonate process demonstration project being sponsored by the Federal EPA and the State of New York. The process involves a spray dryer type approach using sodium carbonate followed by a complex series of steps which ultimately produces elemental sulfur and regenerates the sodium carbonate. The process uses coal for the eventual reduction to produce elemental sulfur. The process has not yet been operated as an integrated system on a large scale.

Work is continuing on two versions of the Citrate process. One is the Bureau of Mines' approach which uses methane as a reductant. The second approach involves a German technology which uses steam stripping to produce an SO_2-rich stream. The SO_2-rich stream can either be converted to sulfuric acid or reduced to elemental sulfur.

Two processes are currently under development for reduction of such an SO_2-rich stream to elemental sulfur using coal, the RESOX process and the

Allied Chemical process. The RESOX process uses a moving bed-type reactor and the Allied Chemical a fluidized bed reactor to contact the coal with the concentrated SO_2 stream. The objective in both processes is to use common coals, such as power plant steam coal, for the reduction of a concentrated SO_2 stream produced from an SO_2 absorption/desorption cycle. If successfully developed, such a process could be coupled with commercially available absorption/desorption processes, such as the Wellman-Lord process.

Economic analyses of these advanced recovery processes, however, indicate that costs will probably be 20-50% higher than the nonrecovery processes. This economic disadvantage will continue to limit the applicability of recovery processes to situations where disposal isn't possible or prohibitively expensive because of local conditions.

PARTICULATE AIR POLLUTION CONTROL - A LOOK AT THE 1980's

Grady B. Nichols
Southern Research Institute

The three well-known techniques for controlling particulate emissions from industrial sources are scrubbers, fabric filters, and electrostatic precipitators. Even though there are a number of particulate scrubber installations operating, both the fabric filter and electrostatic precipitator are expected to be the principal devices for particulate emission control during this decade. This opinion is based on the fundamental difference in the mechanisms by which particles are removed in these devices.

The new source performance standards require a significant collection efficiency for all particle sizes, including the submicron-size fraction from effluent gas streams. The mechanism by which particles are collected in wet scrubbers depends first upon the particle coming in intimate contact with a fluid droplet. However, for the very fine size fraction, the particles behave almost like gas molecules. This causes them to flow around rather than impinging upon the fluid droplet. Thus, the wet scrubber is expected to be used principally for gaseous emission control for large gas volume flow instances with perhaps only a small application to particulate control, principally in the metallurgical industry, in this decade.

Both electrostatic precipitators and fabric filters are capable of meeting the new source performance standards. The selection of which control device is properly based on economics. In those cases where the particulate resistivity is very high—on the order of ten to the power of twelve ohm-centimeters—the economics tend to favor the fabric filter, while for resistivity values less than this, the electrostatic precipitator is usually more economical.

The fabric filter and the electrostatic precipitator differ significantly in their principles of operation. In the fabric filter system, the entire effluent gas stream passes through the fabric filter material. Initially the fabric serves as the particulate removal media. However, a layer of collected material develops on the dirty gas side of the material. This cake serves to augment the collection characteristics of the filter media leading to an increase in collection efficiency with time. As this cake builds up, a concomitant increase in pressure drop across the composite filter and cake develops. When the pressure drop across the fabric filter system exceeds some predetermined value, the bags are cleaned and the cleaning cycle repeats.

The two primary factors governing the economics of fabric filter operation are the replacement costs for the bags and the energy required to sustain the pressure drop across the bags. It is reasonable to expect fabric filter life of about two years. The pressure drop across a fabric filter usually falls in the range of ten centimeters of water.

The electrostatic precipitator differs from the fabric filter in that electrical energy is applied directly to the particulate that is to be removed rather than to the entire gas stream. The energy is used to apply an electrical charge to the particulate material and the removal is accomplished by the action of the electric field adjacent to the collection electrode on those charged particulates. This usually leads to a smaller operating energy requirement for the electrostatic precipitator than for the fabric filter.

Research projects are under way to improve the operational characteristics of the fabric filter, scrubber, and the electrostatic precipitator. The pressure drop across the filter media and dust cake is the source of the primary operating cost of the fabric filter. A research project has indicated that if an electrical charge is applied to the particulate prior to collection, the pressure drop characteristics of the dust cake are significantly reduced. This could lead to a significant reduction in the operating costs of fabric filters for industrial applications.

Both the Environmental Protection Agency and the Electric Power Research Institute are involved in fabric filter research programs. Studies of fabric aging, high-temperature fabrics, felted glass material, cleaning techniques and the influence of the particulate characteristics on particle penetration are active. The improvement of the existing models of the fabric filter system is another significant research effort.

Research into the enhancement of scrubber operation by the electrical charging of the constituents has been conducted by the University of Washington and Air Pollution Technology. In these studies the electrical attraction between the particles and water droplets increases the probability of capture for the finer particle sizes.

Several research projects are currently active on various aspects of electrostatic precipitation. Both the Environmental Protection Agency and the Electric Power Research Institute are sponsoring research in this general area, as well as many equipment suppliers are conducting company-sponsored research projects. The current research topics include novel precharging devices, pulse energization, and configuration changes within the device, as well as an investigation into two-stage collection devices.

The efficient operation of an electrostatic precipitator is dependent upon the optimization of three steps in the collection process: particle charging, particle collection, and the removal of the previously collected material from the collection electrodes. The presence of high resistivity material in the gas stream tends to limit both the charging and collection of the material. In the electrostatic precipitator, the particles are typically charged in an electrical corona. An electrical potential is applied across the electrode system that causes the generation of free electrons in the vicinity of the corona wire. These free electrons attach to neutral gas molecules to form negative ions some of which attach to the dust particles leading to negatively charged dust particles. The remainder of the unattached ions flow through the interelectrode space, through the dust layer to the positive collection electrode and complete the electrical circuit through the power supply.

The current flow through the dust layer is the point in the collection scenario where high resistivity dust leads to collection problems. The current flow through a dust layer establishes an electric field in that layer proportional to the current density and resistivity of the layer. If the dust layer resistivity exceeds some critical value for a given current density, the electric field in the dust layer will be sufficient to cause an electrical breakdown of the gas molecules that are within this dust layer. This phenomenon is termed back corona. A breakdown at this location generates positive ions that are detrimental to the operation of the electrostatic precipitator.

Southern Research Institute is currently engaged in a research project for the Particulate Technology Branch of the Industrial Environmental Research Laboratory (IERL) of the EPA to develop a precharge system that overcomes this particular problem. The current state of development for this research project is that both bench-scale and a 1,000 ft^3-per-minute pilot-scale device has been completed. A 30,000 ft^3-per-minute system is now under construction for evaluation at the Bull Run Power Station of the Tennessee Valley Authority.

This device, shown in Figure 1, consists of a three-electrode charging system rather than the two-electrode system used in conventional precipitators. The third electrode located adjacent to the collection electrode, serves as a sink for the positive ions that are generated by the back corona. This device was designed to eliminate the limitation in performance of electrostatic precipitators imposed by high resistivity particulates. The tests to date indicate that this is a significant breakthrough in electrostatic precipitation.

A second precharger concept, the High Intensity Ionizer, has been under development for several years by Air Pollution Systems. The purpose of this device is to provide a higher than normal charge for all dust particles. Its use would not be limited to the improvement in collection for high resistivity dusts. Figure 2 illustrates the High Intensity Ionizer. This device was originally developed to electrically charge particles to enhance the operation of a wet scrubber. However, because of the superior electrical behavior, in comparison with the conventional electrostatic precipitator, this suggested the possible use in electrostatic precipitation.

This system consists of an array of disc corona electrodes suspended in the center of venturi-shaped grounded electrodes. This system operates with current densities that are several decimal orders of magnitude greater than a conventional electrostatic precipitator and with electric field strengths a few times greater. The purpose for this system is to impart an electrical charge to the particulate that exceeds that normally provided by a conventional system by a factor of three or four. The current research activities center around means for eliminating the limitations in performance related to high resistivity dust and high space charge. This device may also provide a significant improvement in the performance of electrostatic precipitators.

Some significant electrostatic precipitator research is currently under way at the University of Tokyo. Professor Masuda has developed two systems that show promise for dealing with limitations in performance imposed by high

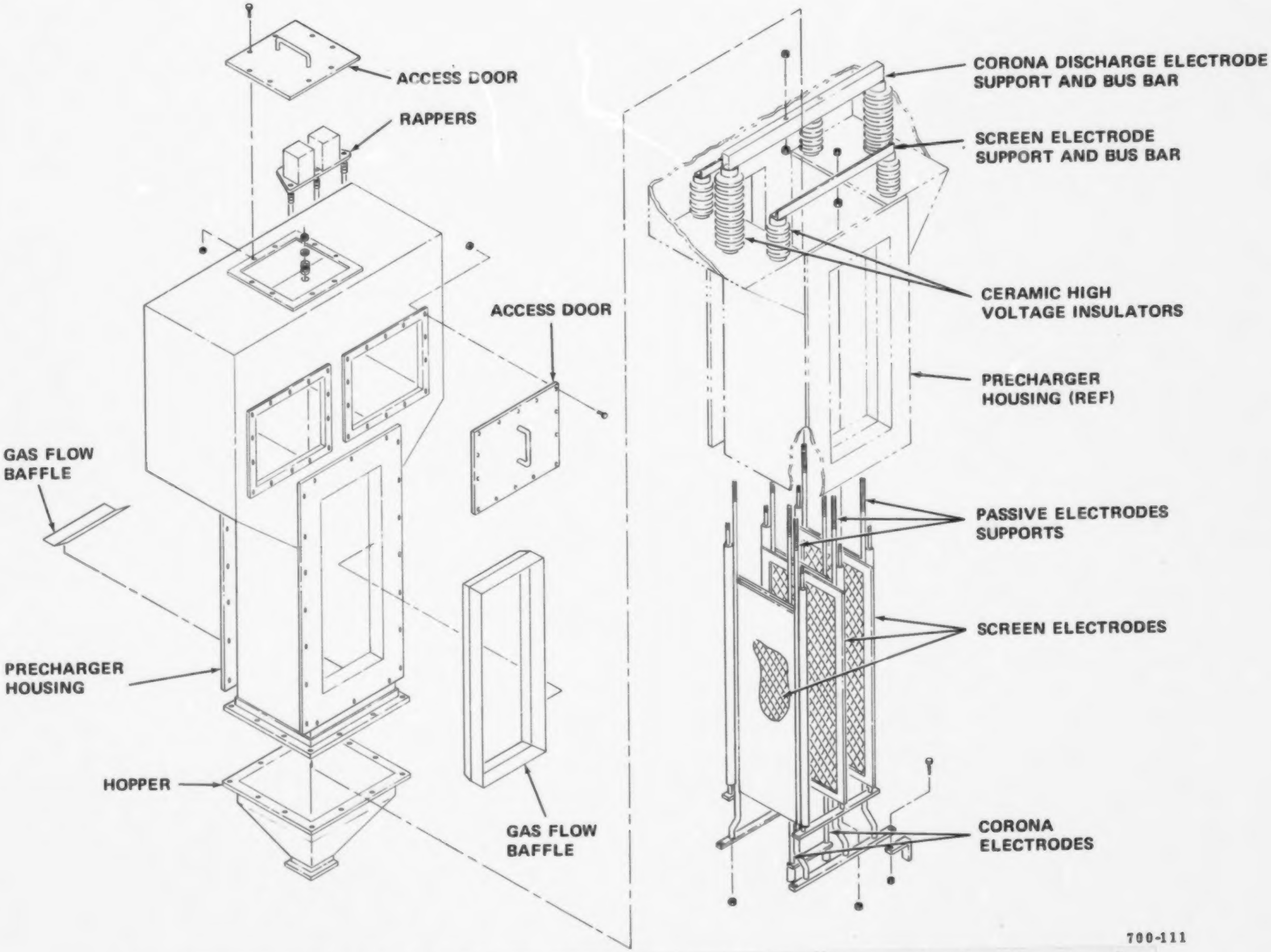
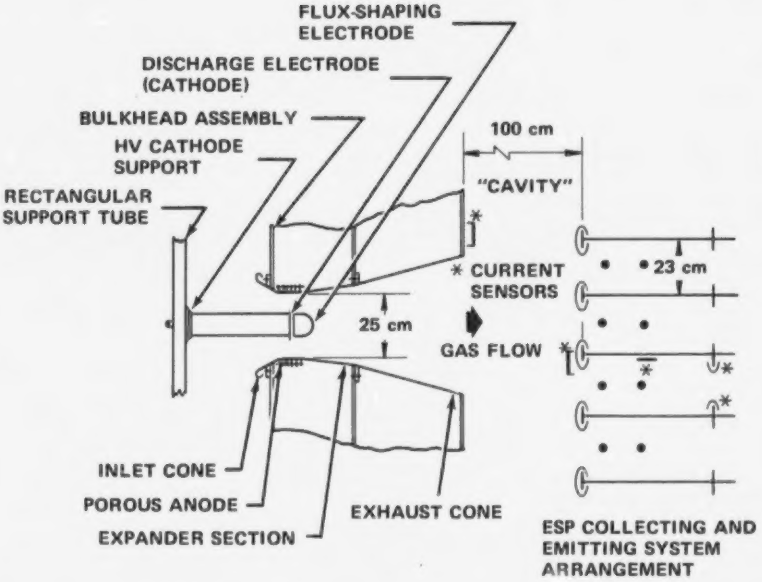

ACCESS DOOR
RAPPERS
ACCESS DOOR
GAS FLOW BAFFLE
PRECHARGER HOUSING
HOPPER
GAS FLOW BAFFLE
CORONA DISCHARGE ELECTRODE SUPPORT AND BUS BAR
SCREEN ELECTRODE SUPPORT AND BUS BAR
CERAMIC HIGH VOLTAGE INSULATORS
PRECHARGER HOUSING (REF)
PASSIVE ELECTRODES SUPPORTS
SCREEN ELECTRODES
CORONA ELECTRODES
700-111

Figure 1. Southern Research Institute three-electrode charging system developed under sponsorship of U.S. EPA, Particulate Technology Branch, IERL.


FLUX-SHAPING ELECTRODE
DISCHARGE ELECTRODE (CATHODE)
BULKHEAD ASSEMBLY
HV CATHODE SUPPORT
RECTANGULAR SUPPORT TUBE
100 cm
"CAVITY"
* CURRENT SENSORS
23 cm
25 cm
GAS FLOW
INLET CONE
POROUS ANODE
EXPANDER SECTION
EXHAUST CONE
ESP COLLECTING AND EMITTING SYSTEM ARRANGEMENT

700-109

Figure 2. Air Pollution Systems' high intensity ionizer.

resistivity particulate. Figure 3 illustrates a three-electrode system that differs in concept from the Southern Research model. This system is designed specifically for pulse energization. A steady direct current collection field is applied across the channel electrodes. The discharge electrode is energized by a pulsing system such that the average current density is controlled by the pulse height, duration,and repetition rate of the pulse system.

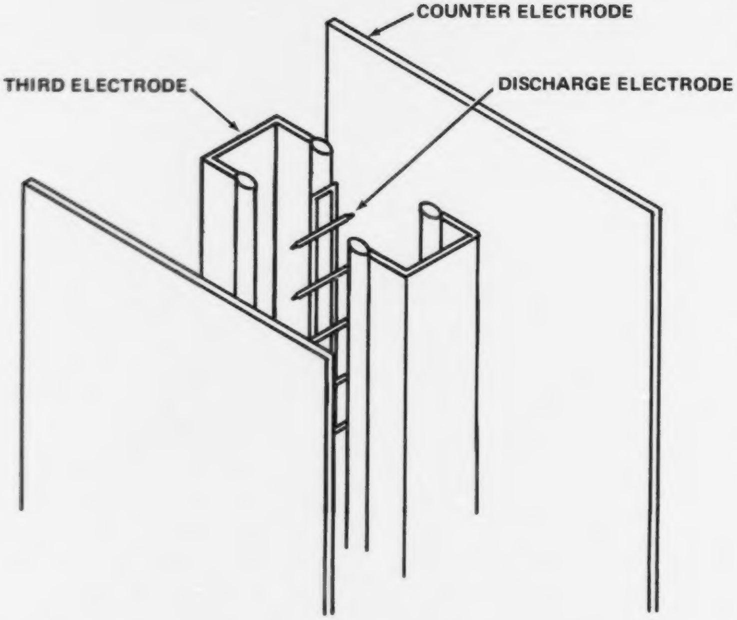
A second system under study at the University of Tokyo is termed a "Boxer" charger. This system, illustrated in Figure 4, attempts to maintain a low average current density by reversing the direction of current flow through the dust layer. The operation could be termed a long pulse system as contrasted with the short pulse systems under study at other locations. At this point in time, the "Boxer" charger is primarily of academic interest.

A number of investigators are studying pulse energizations for electrostatic precipitators. Dr. Harry White conducted the first study of pulse energization during the early 1950's. This system only applied fast rise time pulse to the corona system, but did not maintain a significant electric field for collection. Recently, Research Cottrell and Prof. Lausen of the Technical University in Copenhagen, sponsored by the F. L. Schmidt Company, have made significant progress in the development of pulse energization systems for electrostatic precipitators. In these systems, a steady electric field is applied to a conventional precipitator electrode system. Electrical pulses are superimposed on this steady field to provide a well-controlled current density and average field for the equipment. Thus, normal and perhaps greater values of charge can be applied to the particulate, while the average current density is maintained below the value that would produce back corona. These systems are expected to improve the operation of electrostatic precipitators collecting high resistivity particulate.

Changes in electrical space is another area being investigated at several research laboratories. The standard collection electrode spacing of from 9 to 12 inches seems to have been developed because of a trade-off between the availability of high voltage power supplies and manufacturing tolerances. In the early years, power supply voltages of about 35 kilovolts were just about the state of the art. On the other hand, field erection of collection electrodes could be expected to produce a plate-to-plate tolerance of perhaps 0.5 inch. These factors combine to suggest a plate-to-plate spacing for 9 or 10 inches. Within the last few years some manufacturers have extended this to 12 inches.

It has been suspected that an improvement in performance could be realized if the plate spacing could be optimized. Studies have been conducted over many different plate spacings. One study reported from Japan includes a discussion of the electric field distribution for a range of plate spacing up to about one meter. Figure 5 illustrates these results.

From theoretical considerations, one would expect that there is no one optimum plate spacing, but rather an optimum for a given situation. One significant limitation in performance for electrode precipitators is spark rate. Sparks develop as a flare on the positive electrode. The development of a spark from the flare is dependent upon the value of the electric field


COUNTER ELECTRODE
THIRD ELECTRODE
DISCHARGE ELECTRODE

ELECTRODE CONSTRUCTION OF PAC SYSTEM

700-112

Figure 3. Tokyo University three-electrode system for pulse energization.

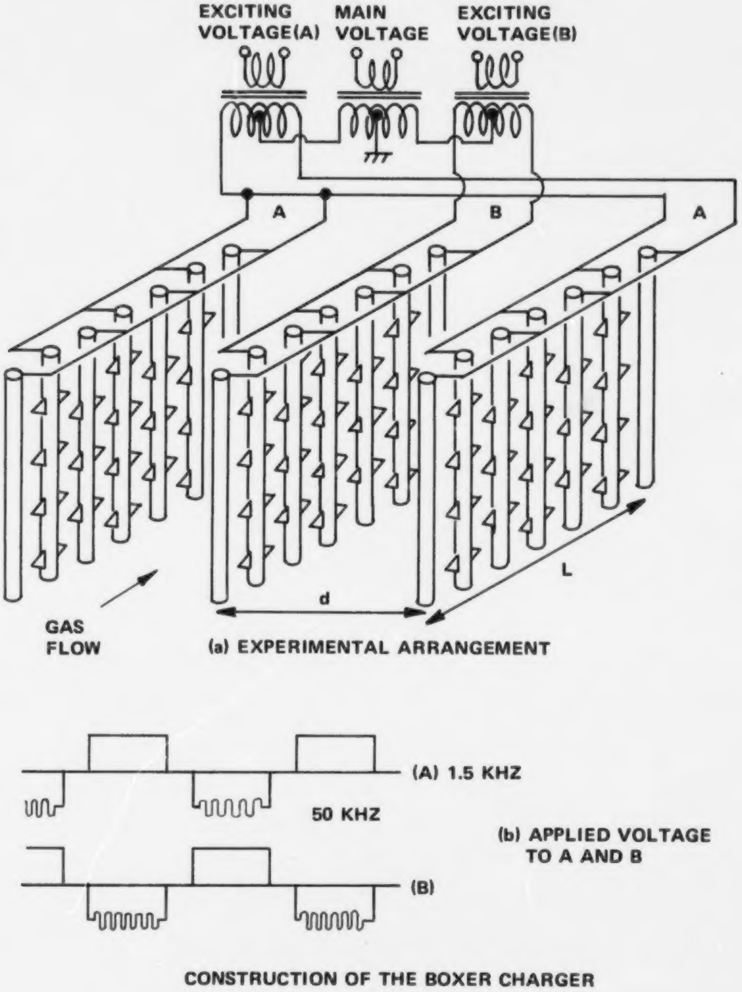
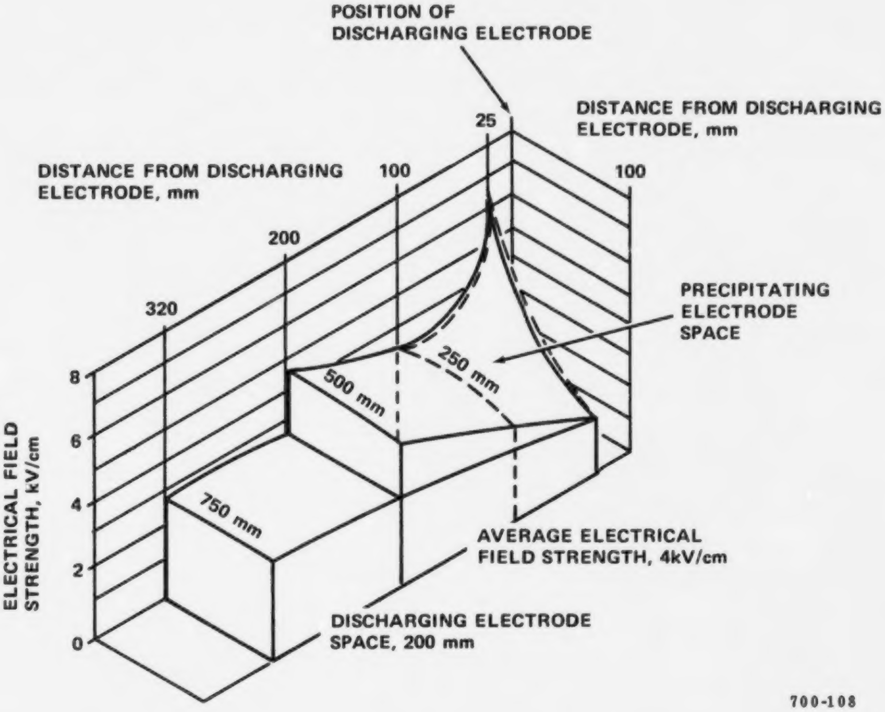

EXCITING VOLTAGE(A)
MAIN VOLTAGE
EXCITING VOLTAGE(B)
A
B
A
GAS FLOW
d
L
(a) EXPERIMENTAL ARRANGEMENT
(A) 1.5 KHZ
50 KHZ
(B)
(b) APPLIED VOLTAGE TO A AND B
CONSTRUCTION OF THE BOXER CHARGER
700-110

Figure 4. Tokyo University Boxer Charger.


POSITION OF DISCHARGING ELECTRODE
DISTANCE FROM DISCHARGING ELECTRODE, mm
25
100
DISTANCE FROM DISCHARGING ELECTRODE, mm
100
200
320
PRECIPITATING ELECTRODE SPACE
250 mm
500 mm
8
6
4
2
0
ELECTRICAL FIELD STRENGTH, kV/cm
750 mm
AVERAGE ELECTRICAL FIELD STRENGTH, 4kV/cm
DISCHARGING ELECTRODE SPACE, 200 mm

700-108

Figure 5. Electric field distribution for variations in electrode spacing in an electrostatic precipitator

adjacent to this flare. If the field is high (a few kilovolts per centimeter) the flare will develop into a spark. The value of the electric field at the plate is proportional to both the electrical space charge and the distance from the corona electrode. Thus, for wider plate spacings, the electric field at the plate will be greater. From this, the optimum plate spacing will be dependent upon the dust loading and particle size distribution for a given application. For low dust loadings of coarse particles the optimum plate spacing will be larger than for high loadings of very fine dust.

SUMMARY

During the decade of the 1980's, both fabric filters and electrostatic precipitators are expected to be used as the primary particulate collection systems for meeting the particulate emissions standards throughout the world. The electrostatic precipitator is expected to be the principal device for installations with gas flows greater than perhaps a few-hundred-thousand-cubic-feet-per-minute of gas flow. In some special cases, where the particulate resistivity is very high or where the fuel supply is highly uncertain, the fabric filter will probably be used. Either the fabric filter or the electrostatic precipitator when designed and operated properly can meet the new source performance standards. The actual selection of which control device should be used should be made on an economic basis.

The wet scrubber is not expected to be a significant part of the particulate control market during this decade for the larger gas flow installations. This device is expected to be used primarily for the purpose of gaseous pollutant control. In these special cases where chemical scrubbing is required, a high quality scrubber may be selected over a combination unit. Specific areas where scrubbers are expected are for the QBOP and cupola installations.

THE CATALYTIC APPROACH TO AIR POLLUTION ABATEMENT

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Engelhard Industries Division
Engelhard Minerals and Chemicals Corp.

INTRODUCTION

The catalytic approach to air pollution abatement presents numerous opportunities for innovation. The catalytic approach includes established technologies as well as emerging technologies that have promising application over the next 10 years. Some established technologies have only very limited markets today simply because legislation requiring their use has not yet been enacted or is not widely enforced.

This paper describes established catalytic processes and several developing catalytic processes that can play an important role in future air pollution control technology.

VOLATILE ORGANIC COMPOUNDS

Volatile organic compounds present a problem as air pollutants because, in the atmosphere, they take part in reactions that produce oxidants and, in some areas, aerosols and smogs. These hydrocarbon or organic emissions can be controlled by afterburners of the thermal or catalytic type. Thermal afterburners contain no catalyst and destroy the organic compounds by holding the polluted gas stream at a temperature above 1300°F (704°C) for 0.3 seconds or longer. Catalytic afterburners pass the polluted gas stream through a bed of catalyst at temperatures ranging from 350°F (177°C) to 900°F (482°C). Residence times in the catalyst bed range from 0.03 to 0.07 seconds.

In June of this year, R. E. Barrett and P. R. Sticksel of Battelle Columbus Laboratories (1) published, under EPA sponsorship, a "Preliminary Environmental Assessment of Afterburner Combustion Systems." As can be seen in Table 1, the total volatile organics emitted from stationary sources in the USA is more than 106 million metric tons per year. When methane is subtracted from that amount, there is left 25 million metric tons per year of volatile nonmethane organics. Of this amount, 16 million metric tons per year are from man-related sources. Over 9.5 million metric tons per year, or 59% of the man-related emissions, are amenable to control by afterburners.

TABLE 1

ORGANIC EMISSIONS FROM STATIONARY SOURCES IN THE USA.

	METRIC TONS PER YEAR
● VOLATILE ORGANICS	
NATURAL SOURCES	85,300,000
MAN-RELATED SOURCES	21,248,900
TOTAL	106,548,900
● VOLATILE NON-METHANE ORGANICS	
NATURAL SOURCES	9,100,000
MAN-RELATED SOURCES	16,112,400
TOTAL	25,212,400

The amount of nonmethane hydrocarbons actually being controlled by afterburners today is difficult to estimate. However, marketing information from the Industrial Gas Cleaning Institute (IGCI) (2) shows that the current total market for afterburners for all IGCI members has averaged only $4 million per year for the last 5 years. This means that a very small percentage of the total volatile nonmethane organic emissions is being treated by afterburners today, even though it is realized that other control devices, such as adsorption, are being used on certain processes where they are more practical.

During the coming years, as tighter regulations are enacted for controlling volatile organic emissions, the advantages of catalytic processes should become more important. Catalytic abatement of volatile organics takes place at temperatures that are considerably lower than those required by thermal afterburners. In addition, the percent conversion of the organic compounds to water and carbon dioxide can be as high as is required. In fact, destruction of unwanted organics to parts per million, and even parts per billion, concentrations is possible. In cases where the concentration of the organic in the air stream is too low to permit self-sustaining operation in a thermal incinerator, a catalytic system can be self-sustaining because of its lower operating temperature. In any case, a catalytic system always uses less fuel than a thermal system because of its lower operating temperature.

A good illustration of the catalytic system, and its advantages, is shown by considering the catalytic process for abating the off-gases from a formaldehyde plant.

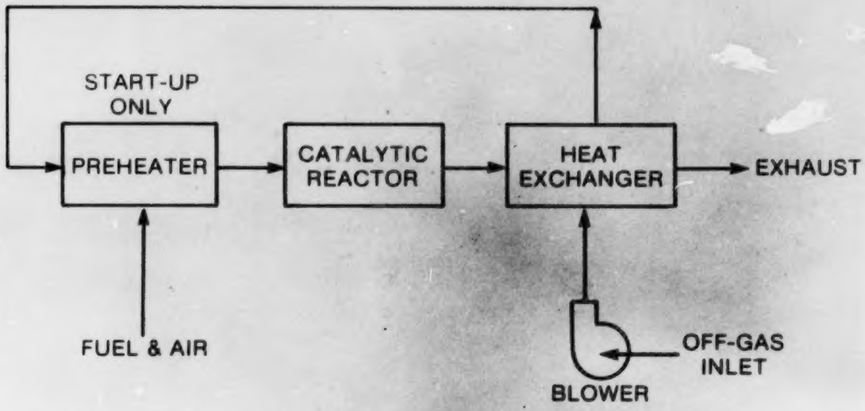


Figure 1. Flow schematic for catalytic abatement of formaldehyde plant off-gas.

Figure 1 shows a simplified flow schematic of the system. The polluted off-gas enters through a blower which may not be needed if the off-gas is available at a pressure greater than 10" water. The gas then enters a gas-to-gas heat exchanger which preheats the incoming off-gas to a temperature that is high enough to promote the catalytic reaction. A burner is used for about 10 minutes when the system is started up after a shutdown. The oxidation of the organic compounds takes place in the catalyst bed and causes a corresponding rise in the temperature of the off-gas. The purified off-gas enters the gas-to-gas heat exchanger where it gives up part of its heat to the incoming polluted gas stream. The purified hot gases still contain enough heat to justify the installation of a waste heat boiler to generate low pressure steam, in cases where there is a need for such steam.

Table 2 shows the conversion of organics that is obtained. All organics are removed to very low levels and the percent conversion of each organic is high.

TABLE 2

CONVERSION OF ORGANICS IN A FORMALDEHYDE PLANT CATALYTIC AIR POLLUTION ABATEMENT SYSTEM.

CATALYST INLET TEMPERATURE: 450°F (232°C)

ORGANIC	INLET-PPM (BY VOL)	OUTLET-PPM (BY VOL)
FORMALDEHYDE	200 TO 500	5
METHANOL	200 TO 700	10
DIMETHYL ETHER	2,000 TO 5,000	75 TO 125
CARBON MONOXIDE	5,000 TO 10,000	30 TO 100

Figure 2 shows the natural gas savings that can be realized in a formaldehyde plant by using a catalytic air pollution abatement system as compared to a thermal air pollution abatement system. By using a 45%-efficient heat exchanger, the catalytic system requires no additional fuel. This advantage will become increasingly important as the price of energy continues to rise.

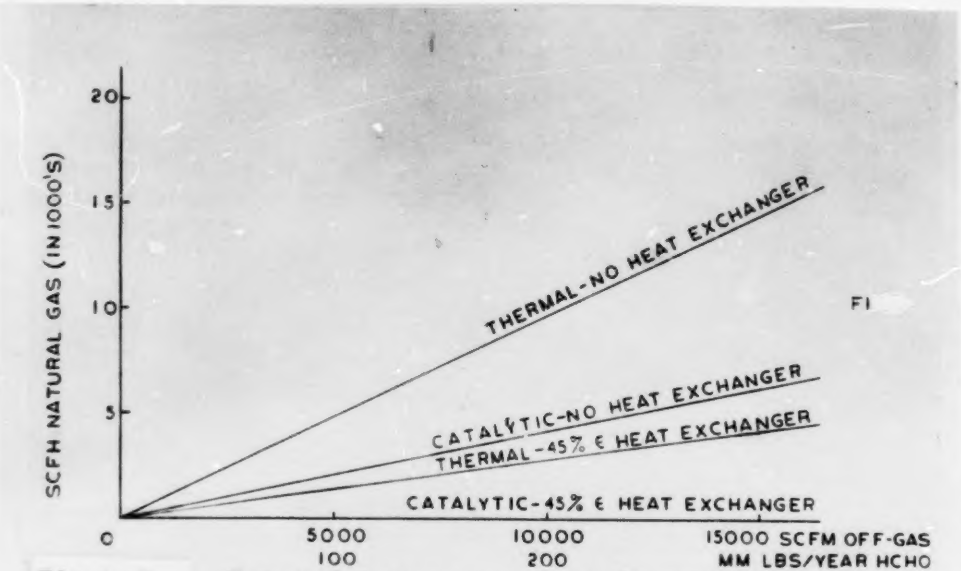


Figure 2. Natural gas usage for thermal and catalytic abatement systems.

Since the catalytic system operates at relatively low temperature, it does not form any additional oxides of nitrogen (NOx). This will be another important advantage of the catalytic process as the concern over NOx pollution becomes more

FORM FOR EPA CONFERENCE MANUSCRIPTS

Please read all attached instructions before you begin typing

TITLE (After first page, use this line for manuscript)

intense in the future.

STATIONARY ENGINES

A developing application of catalytic technology exists in the abatement of hydrocarbons, carbon monoxide (CO) and oxides of nitrogen(NOx) in the exhausts of stationary engines. The abatement of hydrocarbons and carbon monoxide from the exhausts of such engines has been accomplished for years by use of standard oxidation catalysts. Today, there is increased interest in the simultaneous abatement of NOx along with hydrocarbons, and carbon monoxide. The California Air Resources Board (CARB) has recently passed a model rule that requires reducing NOx in stationary engine exhaust to approximately one-tenth of that required by Federal regulations. The CARB regulation also requires that CO emissions be less than 2,000 ppm.

Because of the increasing NOx problem in many areas of the USA, Federal regulations for stationary engine exhaust will tend to become stricter over the next ten years. Modification of engine combustion chambers and/or engine operating conditions to control NOx emissions will not be sufficient to meet these regulations without causing serious increases in fuel consumption. Following is a description of two catalytic processes, one established and one in the pilot demonstration stage, that will allow engines to meet the new California regulations for NOx and CO emissions and also any new Federal regulations that might be forthcoming in the near future.

A catalytic process called the nonselective process is used for the abatement of NOx, CO,and hydrocarbons from the exhausts of stationary rich-burning engines that use sweet natural gas as fuel. This process has been established in other applications and is now being applied to the abatement of engine exhaust. The reactions involved are shown in Table 3.

Table 3. **FUEL-RICH RECIPROCATING ENGINES**

REACTIONS FOR NON-SELECTIVE REDUCTION OF NO_x

STEP 1

$$NO_2 + H_2 \rightarrow NO + H_2O$$
$$NO_2 + CO \rightarrow NO + CO_2$$

STEP 2

$$O_2 + 2H_2 \rightarrow 2H_2O$$
$$O_2 + 2CO \rightarrow 2CO_2$$

STEP 3

$$2NO + 2H_2 \rightarrow N_2 + 2H_2O$$
$$2NO + 2CO \rightarrow N_2 + 2CO_2$$

This process only applies to rich-burn engines, which are engines that are designed so that they can be adjusted to run slightly rich of stoichiometric. Some of the excess fuel is reformed to CO and hydrogen in the engine cylinders so that a slight excess of CO and hydrogen are present in the exhaust going to the catalytic converter. The excess CO and hydrogen is used to reduce the NOx to ordinary nitrogen.

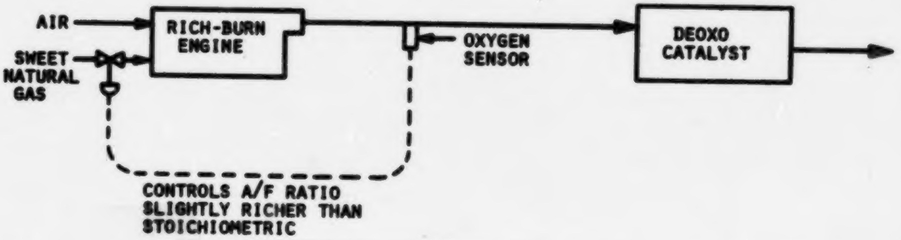


Figure 3. Nonselective NO_x abatement.
Rich-burn engines.

A flow schematic of the system is shown in Figure 3. An air/fuel ratio feedback controller is used to automatically maintain the air/fuel ratio slightly rich of stoichiometric regardless of variations in atmospheric temperature, atmospheric pressure, or the BTU content of the natural gas fuel.

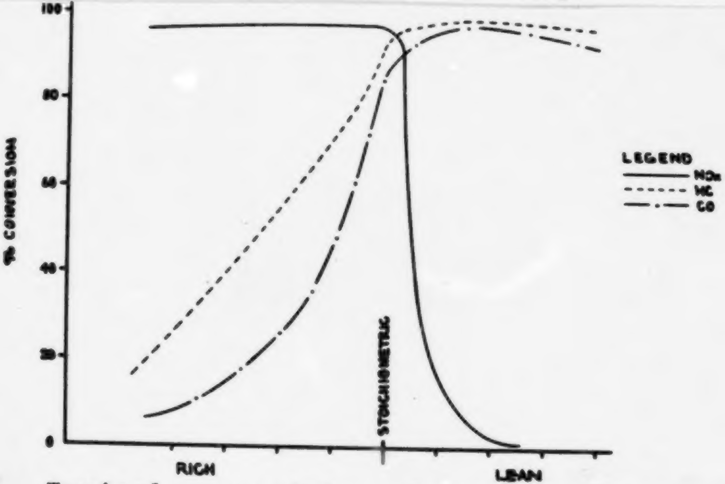


Figure 4. Typical composition of gases exiting catalyst bed vs air/fuel ratio.

Figure 4 shows the conversion of nonmethane hydrocarbons, CO, and NOx in the catalyst bed as a function of air/fuel ratio. It can be seen that when operated slightly rich of stoichiometric, simultaneous high conversion of all three pollutions is achieved.

Another process called the selective catalytic reduction of NOx can be used in conjunction with an oxidation catalyst to abate NOx, CO, and hydrocarbons from the exhausts of lean-burning engines fueled with sweet natural gas. This catalytic process is now in the pilot development stage operating on slip-streams from the exhausts of large stationary lean-burning engines. Lean-burn engines are those that are designed to operate in such a way that there is always 3 to 15% oxygen in the exhaust. It would be uneconomical to use the nonselective process in these cases since additional fuel would have to be added to the exhaust gas to consume all the oxygen before the NOx could be reduced to nitrogen (refer to Table 3).

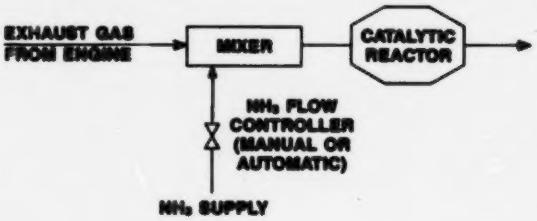


Figure 5. Selective catalytic reduction of NOx.

The selective process shown in Fig. 5 solves this problem by adding ammonia gas to the exhaust gas before it enters the catalyst bed. In the catalyst bed, the ammonia selectively reacts with only the NOx converting it to ordinary nitrogen. The reactions are shown in Figure 6. Catalysts must have the ability to promote the reaction of the ammonia and NOx to form nitrogen and to suppress the formation of additional NOx by the reaction of ammonia and oxygen.

MAIN REACTIONS

$$4NH_3 + 6NO \longrightarrow 5N_2 + 6H_2O$$
$$8NH_3 + 6NO_2 \longrightarrow 7N_2 + 12H_2O$$
$$4NH_3 + 4NO + O_2 \longrightarrow 4N_2 + 6H_2O$$
$$4NH_3 + 2NO_2 + O_2 \longrightarrow 3N_2 + 6H_2O$$

SIDE REACTIONS

$$4NH_3 + 7O_2 \longrightarrow 4NO_2 + 6H_2O$$
$$4NH_3 + 5O_2 \longrightarrow 4NO + 6H_2O$$
$$8NH_3 + 12NO + 5O_2 \longrightarrow 10N_2O + 12H_2O$$
$$16NH_3 + 12NO_2 + 7O_2 \longrightarrow 14N_2O + 24H_2O$$

Figure 6. Reactions for selective reduction of NOx with ammonia.

CATALYTICALLY SUPPORTED THERMAL COMBUSTION

Catalytically supported thermal combustion, known as Catathermal^{tm} combustion, is emerging as a potentially important process for attaining extremely low pollutant emissions in various types of combustion equipment. Most conventional combustion processes have the problem of producing oxides of nitrogen, and, if combustion is not complete, the exhaust gases contain carbon monoxide and unburned hydrocarbons. Also, conventional systems cannot effectively combust gases that have low BTU content.

All of the above problems can be eliminated by Catathermal combustion (3)(4). In the basic Catathermal combustion process, a fuel/air mixture is combusted over a catalytic element, generally of monolithic configuration.

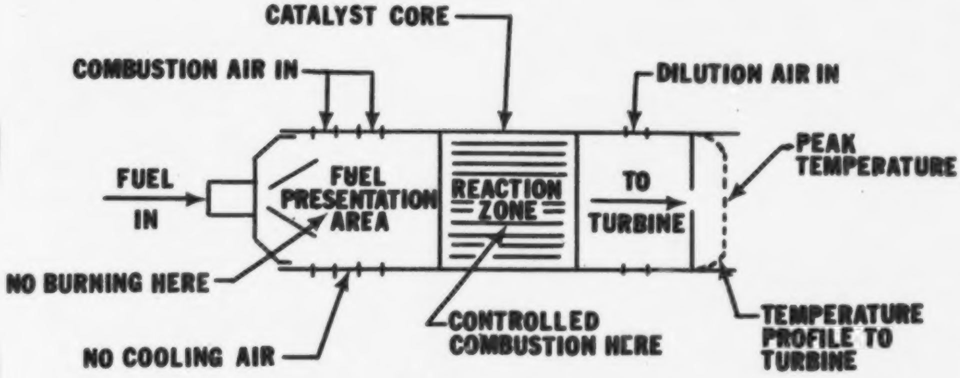

CATALYST CORE
COMBUSTION AIR IN
DILUTION AIR IN
FUEL IN
FUEL PRESENTATION AREA
REACTION ZONE
TO TURBINE
PEAK TEMPERATURE
NO BURNING HERE
NO COOLING AIR
CONTROLLED COMBUSTION HERE
TEMPERATURE PROFILE TO TURBINE

Figure 7. Combustor design concept.

Figure 7 shows a functional sketch of one Catathermal combustor concept that can be used in a gas turbine application (3). The fuel and combustion air are injected into a presentation zone where mixing occurs. The mixture then enters the catalyst where reaction begins and is completed at reaction temperatures below 2800°F (1538°C).

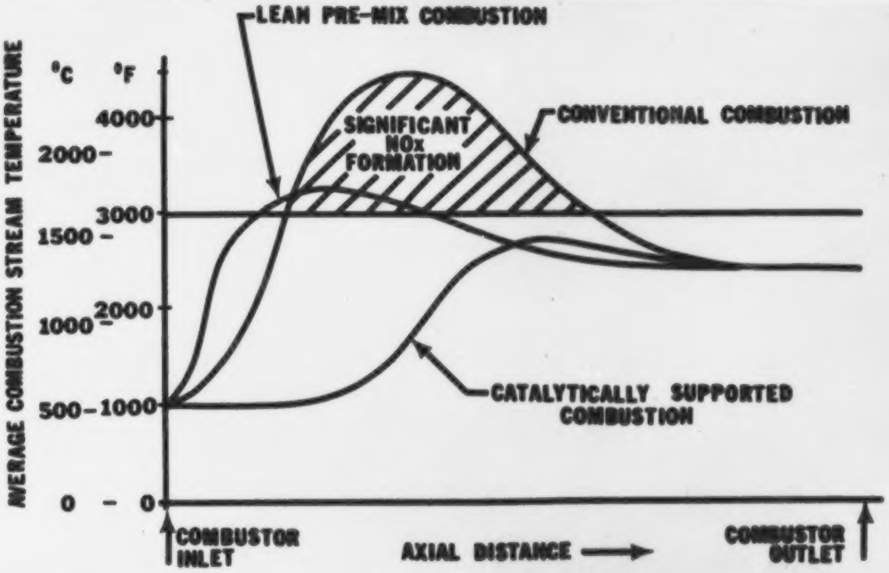
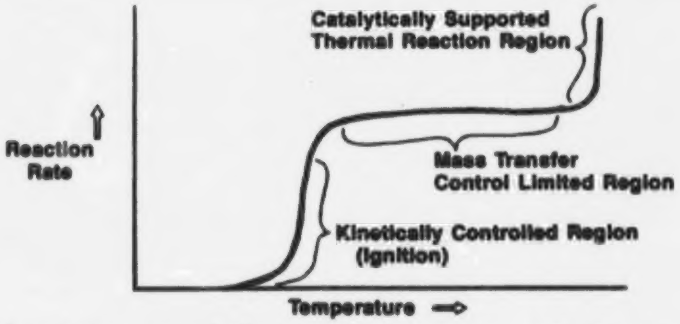


FIGURE 8. **COMBUSTION SYSTEM TEMPERATURE HISTORY**

Figure 8 shows the temperature rise and NOx formation that can occur as combustion proceeds from inlet to outlet of a combustor (3). A conventional combustor produces a peak temperature which is far into the NOx formation region. The flame temperature of a lean premixed combustor is considerably lower but does reach the NOx formation region. The Catathermal combustor maintains peak temperatures well below the NOx formation region. Note that the temperature rises gradually along the length of the catalyst channel, always staying below the NOx formation region. It is this difference between Catathermal combustion and conventional combustion that allows Catathermal combustion to proceed without the formation of additional NOx.



(Fixed pressure, inlet temperature and flow rate)
Figure 9. Reaction rate versus temperature for a fuel oxidation in the presence of a catalyst.

Figure 9 shows the effect of temperature on reaction rates. When the temperature is low, the rate of fuel oxidation is kinetically controlled since the combustion rate is limited by the rate of surface reaction. At higher temperatures, the rate of surface reaction can be so high that the overall combustion rate is controlled by the rate at which fuel and oxygen can be transported to the catalyst surface. As the temperature increases further, Catathermal combustion occurs and the overall reaction rate increases rapidly. The process may be thought to consist of both heterogeneous catalytic reactions taking place on the wall of the catalyst channel at the same time that catalytically supported homogeneous thermal reactions take place within the channel. In addition to producing no oxides of nitrogen, the high degree of completeness of combustion in a Catathermal combustor produces very low CO and unburned hydrocarbon emissions. Typical emissions are shown in Figure 10.

Emissions

- **NOx — *Very low*, less than 5 ppm and in many cases less than 1 ppm.**
- **CO — Less than 30 ppm.**
- **UHCs — Less than 10 ppm. Non-reactive or low reactivity hydrocarbons.**
- ***Note* — Reduced levels of NOx will not result in increased CO and UHC emissions.**
- **No smoke. Particulates are probably very low.**

Figure 10. Typical Catathermal combustor emissions.

In addition to being applicable to gas turbines, this technology can be used for the combustion of conventional fossil fuels, and fuels of the future, such as those derived from coal, or other medium and low-BTU gases.

CONCLUSIONS

In conclusion, it can be said that both proven and emerging catalytic processes should play an important role in future air pollution control technology. The catalytic approach has the advantage of saving energy while allowing pollutants to be reduced to whatever level is required. For the same reasons, pollution regulations that require simultaneous abatement of hydrocarbons, carbon monoxide, and NOx can also depend more fully on catalytic abatement processes in the future.

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USER'S PERSPECTIVE

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Stationary Source Environmental Control Office
Ford Motor Company

The Chairman of this panel has asked me to discuss briefly what industry is looking for regarding the use of innovative technology. With the caveat that there is no such monolith as "industry," and with others in the private section perhaps holding different views, I would like to present some personal thoughts --somewhat prejudiced by over 25 years of experience (in both Government and industry) -- in considering the use of innovative technology as a basis for new regulatory requirements (sometimes known as the "feet to the fire" technique) and the use of innovative technology to meet existing requirements.

First - What are we not looking for regarding the use of innovative technology? Primarily we oppose the use of innovative technology for its own sake, and forcing its use without sufficient study and evaluation of effectiveness, costs, energy penalties, and need. Also, the issue of appropriate technology transfer is often not well considered. The fact that someone sees a new control device in use on a piece of equipment (usually in Germany or Japan) does not necessarily mean that that device can be used on all other similar equipment, irrespective of factors such as age, configuration, special manufacturing requirements, etc.

As a rule, regulatory agencies like to see the use of innovative technology for pollution control resulting from their efforts. It makes good copy and makes points with the head office. It is an article of faith that doing something a new way is always better than doing it the old way -- and if regulations force a new technology, then there is additional justification for the governmental program responsible. Some governmental programs sorely need this additional justification and rationalization for their existence -- and in obtaining these "credits," some agency advocates of forcing innovative technology are often led by what they want to find.

There are many examples of implementation of ill-conceived innovative technology. During the crusade to establish air pollution control schedules for the steel industry, the U.S. Environmental Protection Agency (EPA) proposed a number of requirements as representing Reasonably Available Control Technology (RACT). In fact, many of these requirements are actually based on the use of innovative technology. The confusion is understandable since RACT is a rather subjective standard, often established as the result of technical inspiration of a nontechnical person (e.g., a lawyer). Among the costly innovations which have been unsuccessful during this crusade are pipeline coke oven charging and scrubber coke cars. Others, primarily involving sophisticated, energy intensive, fugitive emission controls, are being questioned on the basis of cost-effectiveness, which I will discuss later. Among other misdirected "technological pushes" are some of the advanced wastewater treatment requirements for municipal systems. Also, uniform requirements to control (VOC) emissions from coating operations, based upon the limited use of innovative water-based coatings, is completely inappropriate.

In the June 1980 issue of the EPA Journal, under the heading "Innovating To Comply" is a report of an Innovative Technology Order issued by EPA to permit a number of industrial boilerhouses to meet Ohio's unique particulate regulations. The technology involves exhausting a portion of the flue gases from the hopper of a standard mechanical collector, and passing it through a baghouse. This improves the efficiency of the mechanical collector and subjects a fraction of the flue gases to fabric filtration. For some types of industrial boilers, this system will provide adequate control for meeting Ohio limits, without having to install high efficiency collectors, such as baghouses or electrical precipitators sized for the entire effluent volume.

In the considerable amount of publicity that accompanied the issuance of this Innovative Technology Order, much was made of the cost savings involved in avoiding the installation of high efficiency collectors to meet the Ohio regulations. This self-congratulation was somewhat overdone. The fact is that the use of this "innovative technology" should not have been required at all.

First - Because of a 1972 error in the drafting of the Ohio regulations, the limits applied to industrial multiboiler configurations are inappropriately stringent -- the most stringent in the country. The Ohio regulations require the use of baghouses or electrical precipitators on some existing industrial boilerhouses. Administrative inertia and political considerations have prevented the correction of the error.

Second - For engineering and other practical reasons, high efficiency mechanical collectors are the most appropriate retrofit control devices for industrial boilers. In fact, most State regulations and the original 1972 EPA State Implementation Plans (SIP) guidelines specify limitations achievable with the use of mechanical collectors.

Third - This technically innovative approach is not cost effective. At one boilerhouse familiar to the author, mechanical collectors remove 1,685 tons of particulate per year at a cost of $120 per ton. The use of the EPA-recommended innovative technology would result in the collection of an additional 31 tons of particulate per year at a cost of $4,100 per ton. These costs do not include the significant energy penalties involved in collecting the incremental 31 tons of particulate.

This example provides the basis for the second part of this discussion -- What are we looking for regarding the use of innovative technology? We are looking for cost-effective/energy-effective, engineeringly practical methods of control -- regardless of whether or not they will exactly meet regulatory emission limits. I am not saying that regulatory limits should be disregarded -- they cannot, because of legal requirements, and should not be disregarded. Rather, the author advocates that in developing and administering regulations, Government Agencies first look to the technology (available and innovative) for the most cost-effective, etc., approach; then, look at the regulatory limit to see if it can be adjusted to be consistent with that approach.

This approach could require case-by-case consideration and the use of administrative discretion. It requires a mature and informed attitude by regulatory agencies, similar to the "best practicable means" approach, used effectively for industrial sources in England for over 100 years. The 110th Annual Report (1973) of the Alkali and Works Inspector contains the following quotation:

> "I have heard it said by a well-known authority from abroad, who has studied the international control scene very carefully for the last 17 years, that when one applies scientific principles and ideas on a grand scale, making use of computers, telemetering, air quality criteria etc., one finally ends up with 'best practicable means.'"

For those considering or advocating the use of innovative technology, practicality and cost-effectiveness should be given first priority. The scrap yards are full of discarded good ideas that didn't work because they were impractical.

Thus, the recommended approach would be to examine the cost-effectiveness of all control technologies (including innovative technologies). Determine if any real adverse air quality effects would occur if the most cost-effective control technology were used; if not, base regulatory requirements or adjust existing regulatory limits to permit the use of the most cost-effective technology. A common-sense approach to air pollution control, such as this, would truly be innovative.

It was stated earlier that regulatory agencies like to see innovative technology employed as a result of their efforts. This is in conflict with the usually held view that innovation is anathema to a regulator. That is, it forces decisionmaking associated with some risk. It requires making a judgment in the face of unknowns. The regulator must take a gamble, and there is no benefit to him or her for assuming the risk -- as opposed to other sectors of society, in which innovation can lead to benefits. This conflict between potential program credits and unrewarded risks, has led to delayed and confused (at times, schizophrenic) governmental action regarding approvals for innovation. Before a common-sense approach can be taken in reviewing innovative technology on the basis of cost, cost-effectiveness, etc., it is necessary to resolve this conflict. There must be a mechanism established to objectively assess the risks of innovation and provide the innovator with protection in the event that the new technology does not fully comply with regulatory requirements. At present, these evaluations are usually made by a permit-processing engineer. Such people usually have limited discretion, and as a rule, do not take risks. The EPA innovative technology order procedures (under Section 113(d)(4) of the Clean Air Act), which are actually a negative and restrictive approach, should be modified to encourage innovation.

In summary, governmental action is a major factor in the introduction of innovative technology. Not all innovations, irrespective of public relations benefits, are desirable. There is a need to develop administrative mechanisms to encourage the use of practical, cost-effective new technologies.

Question (Frank T. Princiotta): I think we would take the opportunity now for some questioning of our panelists by the audience. I would like to follow up on Victor Sussman's major theme, the impact of the regulatory process on innovation.

I want to ask Martin Collins to comment first because I think he represents a somewhat unique industry in automobile catalyst research. It's safe to say that without Government regulations very little would have been done as far as additional catalyst research in the automobile sector is concerned.

Response (Martin F. Collins): As you say, without legislation there would be no motivation to spend money on research. What I can report from the other end is that with the catalytic approach, since we do have such a wide background in that, many times we do have the solution already in hand and are applying it to other industrial processes.

Then it's very easy to apply it to air pollution abatement. We have to leave it up to the Government regulatory bodies and the users to make the necessary trade-offs to arrive at the most practical piece of equipment. We find many times that once a regulation is in effect -- and I don't think anyone argues with the need for such regulation, for instance, in the State of California -- we then find that manufacturers are about to lose their market in the area to competitive methods such as gasoline engines losing out to electric motors. We find that the catalytic approach can give them competitive parity in those areas.

Response (Victor H. Sussman): There's no question that without regulations there would not have been the catalyst unit, the safety control, or other controls placed on the automobile, because there is no economic incentive. There's no competitive advantage to putting a catalyst on a tailpipe and selling a car. The automobile industry supported uniform regulations and clearly indicated from the very beginning, in all of the hearings on the Clean Air Act, that without regulation there would not be any controls. There was no incentive for voluntary controls that did not provide a competitive advantage.

Question (Frank T. Princiotta): Grady Nichols, how about your perspective? You have seen new source performance standards change at least a couple of times in the utility area; what is your impression of the impact of regulation on the technology innovation in the particulate area?

Response (Grady B. Nichols): From my point of view, the cranking down of the emission limitations is a heavy motivator for some aspects of the research that we seek at Southern Research as well as in other countries. On the other hand, some of the developments, such as the pulse power supply development, really could have been developed by the company itself as a means to enhance its position in the market.

Without the regulation there would have been a rather limited market. My experience is more readily applicable to the utility industry, and they have been in the air pollution control business for quite a long time.

Question (David Stephan, Industrial Environmental Research Laboratory, Cincinnati): I have a question for Mr. Sussman. He recognized that there was at least one area in mobile source control where regulations should have been placed as a forcing function on innovation.

What are the kinds of the criteria, Vic, where you see regulations also being forced by regulations; and is that a desirable thing? Do you have any general thoughts on that?

Response (Victor H. Sussman): I don't question the need for regulations in all areas. The private sector will not do anything in the area of pollution control unless there is an economic advantage, and the regulations bring these external costs into the private sector, and there was no argument. I was not advocating doing away with regulations.

What I was advocating was almost the same thing that Doug Costle said when he talked about 113-D of the Act. The regulations should be based on cost-effectiveness and meaningfulness rather than seeking more control irrespective of meaning, need, or cost-effectiveness. Also, some of the bureaucratic inhibitions to technology innovation should be done away with. I tried to list them, but Doug Costle did a much better job of listing those problems. I wasn't advocating that we do away with regulation. There is no question but that these regulations are needed.

Industrial Wastewater Pollution Control Technology

Chairman:
Gerald N. McDermott
Chairman, Industrial Waste Committee
Water Pollution Control Federation

Panelists:
W. Wesley Eckenfelder, Jr.
Robert E. Pailthorp
John H. Robertson
James W. Patterson, Ph.D.

INNOVATION, RETROSPECTS, AND PROSPECTS IN INDUSTRIAL WASTEWATER TREATMENT

G. N. McDermott, Chairman
Industrial Waste Committee
Water Pollution Control Federation

INTRODUCTION

The four engineers who have been selected for this panel are outstanding representatives of the practitioners of the application of technology to control water pollution from industrial manufacturing activities. There is a reason this panel is composed of practicing engineers as opposed to technologists involved more directly in research and development. This choice follows from the definition of innovation as the application of inventions or scientific discoveries for some useful purpose. This definition of innovation distinguishes innovation from inventing and from basic research. I trust we will naturally concentrate on innovation by listening to engineers who put the results of research to work. One type of innovation is to improve the economy of existing nominal treatment processes. Another is innovative technology for higher degrees of general treatment. Still a third is aimed at special treatment needs such as the removal of toxics.

In this discussion, innovation is intended to be distinguished from basic research by a test of status of development; innovation involves applying previously existing scientific observations or phenomena in a way or by use of a device which has not been fully applied previously.

My role here is to contribute my thoughts as a panel member. I am privileged to do this first in the order of presentation among the panel and then to introduce the panel. Finally, I will moderate the exchange among panel members and with the audience. It is not my role to lay out the grand plan of attacking this problem and call on each panel member for a piece of the whole. No, each panel members is free to speak his piece. We only share the common objective of contributing to the many remarks and discussions going on lately in efforts to expedite scientific advancement on every front. Ours happens to involve the discovery and application of technical knowledge which will enhance and maintain the quality of the environment and particularly that for industrial wastewater control.

The interest of the Government, I think, in this instance is nurtured by the Clean Water Act of 1977. This law speaks to innovative technology in a couple of places. Congress is obviously interested in accomplishing the goals of the Clean Water Act more economically than it would be met by presently practiced technology.

A real gain in economics and energy use could go far in silencing the cries of industry against unjustified, untimely, and unrewarding controls.

A real gain in economy of treatment could strengthen the resolve of Congress to see this catch-up program in water quality control through to its accomplishment. No doubt, lawmakers are astounded at the great financial commitment involved in the program as it unfurls in the municipal facility needs lists that are generated periodically. Indeed, the talk has occurred among individual lawmakers of eliminating funds for the Construction Grants Program from recent budgets. For some reason, the Administration as represented by EPA Administrators has lent support to this sentiment and dwelt on ending the Federal Grant Program in documents discussing future plans. I question the wisdom, if the same requirements or objectives of the Act are kept. Shifting the cost from the Federal to State or local sources of funds will not alter the total markedly. My own advocacy to the solution to the Federal program and Federal income problem is along the lines of the proposal of the Businessmen's Roundtable. A part of their regulatory reform proposals is to proceed on the basis of sound scheduling of rational programs balanced with the nation's resources and funds to carry out the programs. Scheduling will require setting priorities so that critical things are attacked first within our economic ability. Other objectives would be scheduled for later times when they will achieve the needed priority.

You may think I am straying from the subject of innovation in industrial wastewater treatment. The thrust of my comments should center on industrial waste treatment, true, but the community waste systems involve on the average 15 to 20 percent by volume of industrial wastes; so the two subjects are inseparable. There is a definite connection between the status of the Municipal Grant Program and the potential use of innovative technology. I have a low expectation of there being a great deal of energy saving and net-cost-saving technology forthcoming in time for the 1983 deadlines or currently indicated end of the grant program, but there will undoubtedly be some.

One of the problems I think we should be concerned about is that of getting any innovative technology ready for large-scale use in the current Federal Construction Grants Program. By the time the innovative processes are installed, developed, perfected, and proven, the opportunities left may be quite limited. Presently, the innovative technology concept of the grant program typically involves only a small part of the total community facility included in a grant proposal. I do not believe there is a definite priority universally given to the total projects that use innovative technology though this may vary from State to State I understand. If a high priority were given projects incorporating a significant amount of innovative technology, proven technology might be available in time for other projects. I think any lack of provision for rapidly proving out innovations is a serious omission in the law and its application. There would be a need to make some tough decisions about the extent of use of innovative technology that would give a project high priority, but I think they could be rationally made. The funds for such priority projects would logically come directly from nationwide funds rather than the funds allotted to states. This is justified because the results will have multi-State ultimate use if proven effective. Such an innovative technology priority system will greatly improve the likelihood of innovative technology playing a big role in the program.

THE PAST

A look at the occurrence of innovation in the past may provide us with a harbinger of the future of innovation in water treatment technology. The technology development record we would all like to point to with pride would relate the dates of initial major developments and note subsequent successive giant strides toward less costly, more efficient or otherwise superior technology. So I attempted to look at such progress for technology that we know has advanced well in such a progression for purposes of comparing it to our wastewater technology. Recently a Mr. Sassin, writing in Scientific American, presented graphs showing energy efficiency improvement over the years in steam power use (Figure 1)(1). Beginning with the development of the Newcomen engine, circa 1720, steady improvement is indicated. These major steps in such improvement occurred rather regularly. The Watt engine came about 1760; the Cormich engine 60 years later; the triple expansion engine in the 1880's; and the high-temperature steam turbine around 1940. Note that the ordinate is a log scale. Improvements, in other words, have increased with time exponentially.

Progress in the energy efficiency of light came much faster, Figure 2. From an early beginning with candles came the first Edison lamp; then the Tungsten filament lamp, the sodium, mercury and finally the fluorescent lamp of a few decades ago.

A similar picture is obtained with respect to one industrial product, namely ammonia, Figure 3; the initial Haber process energy efficiency was around one percent. In the next 50 years that efficiency has been increased by innovation to 50 percent, a remarkable achievement.

I would have liked to have been able to present the same sort of a plot for the wastewater treatment process or at least the use of energy in the wastewater treatment process. I found that I did not have the data to do it and could not come up with anything of use. I considered the activated sludge process alone in this attempt. The energy efficiency of this process involves the efficiency of electric motors and of air compressors and of pumps. I presume there have been advances in the energy efficiency of these devices. But such would not really reflect a more efficient process. Rather unique to the process is the transfer of oxygen to wastewater. Perhaps we should all be chagrined by the realization that the profession is just in recent years reaching consensus on determining the energy efficiency of the various aeration devices. The fact that many such devices are being marketed currently and that very few have fallen by the wayside leads to a tentative conclusion that no quantum jumps have been accomplished.

However, there is, according to the equipment manufacturers, good recent news about an improvement in oxygen transfer efficiency in a rectangular aeration basin. Traditionally, the aerators have been located near one sidewall and paralleled to the long axis of the basin. This was considered desirable to obtain a strong rolling action of the liquid. A rolling action was desirable to keep the biological matrix in suspension. Recently, at least two equipment makers have claimed that the placement of

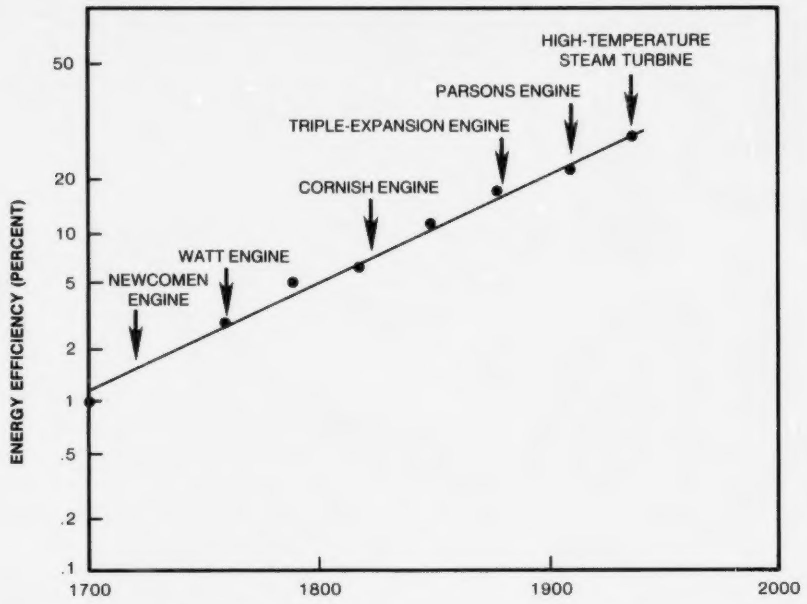


Figure 1. Energy efficiency improvement in steam power use

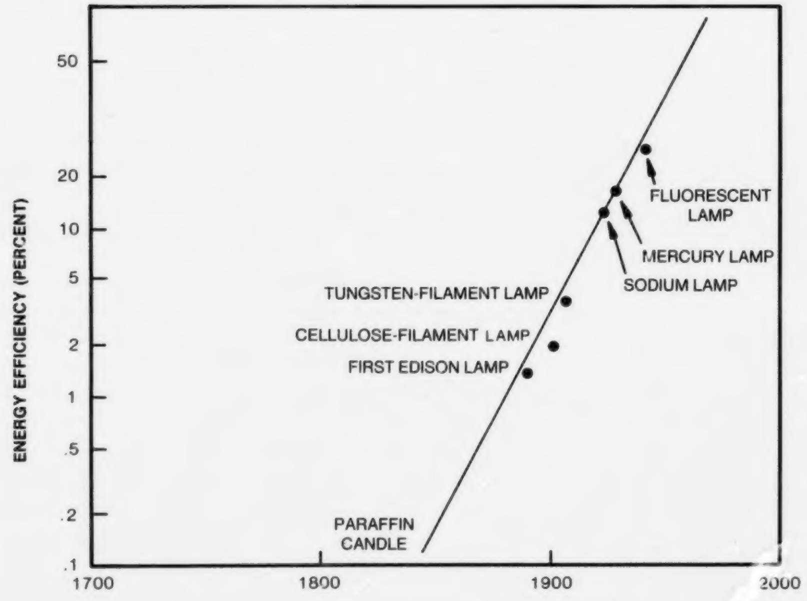


Figure 2. Progress in energy efficiency of light generation

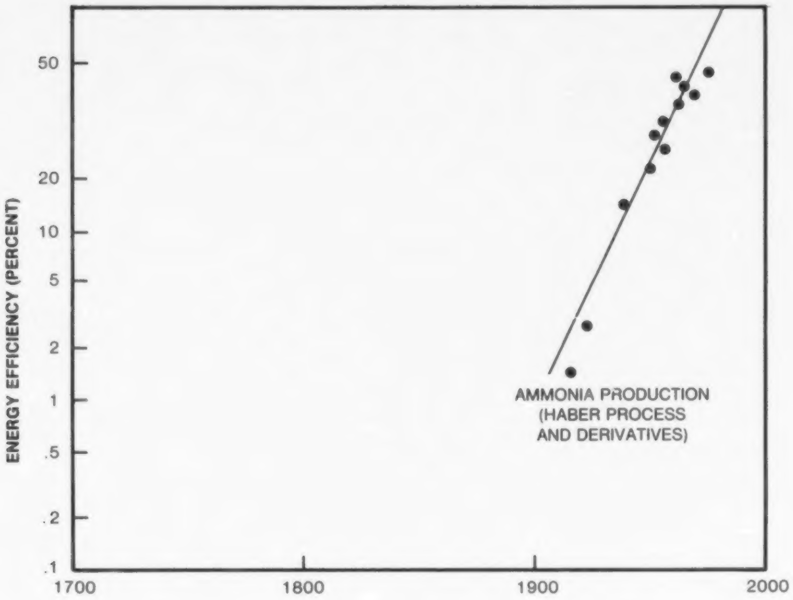


Figure 3. Energy efficiency of ammonia production

such aerators in the middle of the basin along the center line will increase oxygen transfer about 15 percent(2). This information reminded me that quite a few years ago one equipment manufacturer departed from the usual aerator placement by having some rows of aerators at angles, I think, and even crosswise to flow. This equipment did compete very effectively where equipment specifications were set to meet certain oxygen transfer quantities, I have been told. My point is that if my knowledge of the events is correct, a decade or more lapsed before the discovery of this innovation was formally recognized and technically explained. Notwithstanding, this improvement in energy efficiency of 15 percent or even of 10 percent is an outstanding achievement, considering the great amount of energy consumed in such systems nationwide.

Innovation in biological treatment of municipal and industrial wastewaters could include changes in design or operations that would accomplish savings in capital costs or operating costs other than for energy. Again, there is no design or system that has proven so much superior that others have been outmoded. The advances that have been made have not, in other words, been major jumps. A good deal of the costs of construction are those shared with any construction--concrete, earth moving, steel--so that capital savings in construction are shared by the wastewater treatment processes with a myriad of other construction. So the burden for this particular potential saving from innovation is on new construction materials, methods of construction, etc., and is not unique at all to wastewater treatment.

WHAT ARE SOME RECENT INNOVATIONS?

Pollution Engineering Magazine has for the past four years conducted an Awards Program for companies in the business of developing and/or manufacturing products or processes whose ultimate application is for the measurement or control of pollution. Five-star awards are given to 50 entries selected by a panel as deserving national recognition because they had developed a significantly innovative device or process during the year(3).

The following are the recent selections in the water pollution control area which involved innovative treatment:

Use of hydrogen peroxide and short wave ultraviolet light for treatment of such explosive chemicals as TNT and RDX.

Sludge concentrator with major energy conservation advantage.

Rapid sand filter air mix and pulse mix systems to prolong filter runs.

Oil skimming device.

Tannery wastewater treatment procedure involving a five-step biological treatment.

Wet air oxidation of pulp wastes to eliminate landfilling and product ruin.

The September 19, 1980 advanced notice of proposed rule-making by the U.S. Environmental Protection Agency concerned extensions to industrial NPDES discharge permits for installing innovative technology. In that proposal an appendix was provided containing "a partial listing of technologies which the Agency believes may satisfy the requirements for a 301(k) compliance extension ." The Agency goes on to caution that the listing does not mean automatic qualification but as a "basis for comments." The list appears quite up to date and extensive and is incorporated below. The EPA cautions that the list may not be complete(4).

GENERIC END OF PIPE TECHNOLOGIES

Supercritical CO_2 Regeneration of Activated Carbon - Traditionally activated carbon has been regenerated by thermal processes. A method has been developed whereby carbon can be regenerated with supercritcal CO_2 without removing carbon from housing. Compared to pyrolysis, the energy savings are expected to be substantial.

Microfiltration may be applied to remove metals, organics, and inorganic pollutants. It may be applicable to industries such as coil coating or porcelain enameling.

Electrochemical Chromium Reduction involves an electrochemical reaction in which consumable iron electrodes generate ferrous ions in the presence of an electrical current. These ions react with chromate ions in solution, producing chromic hydroxides and ferric hydroxides which can be removed by settling without the need for further chemical addition. This method may also be effective in removing zinc and other heavy metals.

Filter Coalescence involves the coalescence and separation of nonemulsified oil from wastewater and could be used as a secondary treatment for oily wastewaters following emulsion breaking or suspended solids removal.

Electro and Donnan dialysis may be applicable to in-plant concentration and recycle-reuse for wastes such as those from metal finishing.

Ozonation may be applicable for destruction of iron-complexed cyanides, possible in conjunction with ultraviolet light. Alkaline chlorination, a method commonly used to remove cyanide, requires more extensive contact times to be effective in destroying these complexes.

Ozonation may also be used for oxidizing phenols and other organics contributing to BOD and COD. It completely degrades many organics to compounds which are less harmful. It has been tested on municipal wastewaters where it has reduced the phenol content from 0.5 to 0.003 mg/l. Ozonation may be applicable in industries such as coil coating or plastic forming.

IN-PLANT TECHNOLOGIES

Metal Industries

Metal Finishing: For electroplating wastes the use of in-process recovery techniques could result in the reduction of wastewater pollutants and hazardous solid wastes. A very promising system has been developed which might be used on copper, cadmium, zinc, nickel, and chromium plating.

Inorganic Industries

Titanium Dioxide: Reduction of toxic metals can be achieved by aeration in the presence of ferrous iron. Toxic metals can be reduced by aeration of the wastewater in the presence of ferrous iron to half or less the concentration attainable by conventional alkaline precipitation. This technique is particularly applicable to wastes containing ferrous iron with toxic metals such as titanium dioxide, sulfate process wastes, or pickle liquor. However, it can be used on any toxic metals waste stream with the addition of ferrous iron. This treatment produces an easily settled or filtered waste. Results are equal to or better than those obtained by sulfide precipitation, without adding sulfide to the waste stream.

Electrical and Electronic Components: In the semiconductor area, industry is experimenting with plasma etching and dicing. If developed, this would result in the elimination of a substantial portion of the discharge from this industry. For lamp filaments manufacture, major corporations are developing a mandrelless process which eliminates the need for process water.

Leather and Food Industries

Leather Tanning: Combined solid waste management facilities could be considered for small and potentially effected plants in the leather tanning and finishing industry. The facilities could include combined ("coop" or similar) hazardous waste dewatering and disposal, and resource recovery (i.e., chromium).

Food: By-product recovery and animal refeeding of wastewater treatment sludges from food processing plants could be undertaken, with special emphasis on sludges generated with the assistance of chemical coagulants. Such a project could be cooperatively developed and monitored by EPA, FDA, and USDA to ensure compliance with existing regulations and to enhance industry visibility and acceptance.

Meat Packing: Energy-efficient wastewater treatment technologies which minimize direct energy consumption and utilize secondary energy sources (i.e., waste heat addition to efficient aeration systems in cold climates) could be considered. Such a technology might be single-stage high solids activated sludge with extended aeration. This system could be applied to meat packing wastewaters in northern climates to provide concurrent nitrification for consistent year-round removal of ammonia.

Pulp, Paper, Textile, Paint Industries

Uddeholm Ion Exchange: This process enables reuse of substantial quantities of bleachery effluent after treatment in ion exchange columns.

Paint: Paint and ink wastewater can be recycled into product after using separation technologies such as ultrafiltration.

This ends the EPA list. I would like to mention a few other process developments I believe could be considered innovative.

Dr. Jerris gave birth to an innovative device for maintaining organisms in waste treatment in the 1970's, namely the use of an expanded sand bed for the surfaces for film growth. The process has been tested for both aerobic and anaerobic treatment. I don't know that use has progressed to the point of establishing the competitive position of the processes. Certainly the process must be included in a list of the potentially innovative technologies(5).

Anaerobic treatment of mainstream flows, as contrasted to sludges or concentrates, has experienced a recent increase in interest. A great deal of laboratory and even field experience has evolved over the last thirty years in such processes. The new development then was the use of a media on which surface films of anaerobic organisms could develop. McCarty pioneered the basic research of this approach(6). This idea has been put to work in a plant using proprietary devices in the last year or two. It is claimed the treatment fits in the competitive picture as treatment for major reductions before a treatment for a high-quality effluent is applied such as treatment of high-strength wastes before discharge to a municipal system. The economics are aided if the waste is produced at higher temperatures.

In about 1978, as reflected in the U.S. literature, we began to learn of development of an anaerobic treatment for mainstream wastes apparently led by Gatze Lettinga of the Agricultural University, Delft, The Netherlands(7). The novel features of the process are an upflow mode via a distribution of incoming wastes at the bottom of a deep tank and collection of gases well below the surface in the upper portion of the vessel by a system reminiscent of an Imhoff tank. Thus the upper layer now free of gas bubbles acts as a settling chamber to enable return of settleable solids into the mid-layer. The developers claim a layer or blanket of granular anaerobic sludge is maintained in the mid-depth region. The system is being experimented with at two locations in the country.

During the past year or so, Dr. Friedman of Syracuse University has provided an interesting innovative concept of using rotating biological contactors in anaerobic treatment for treatment of high-strength wastewaters. Based on bench scale pilot plant data the process can attain high quality effluents with relatively low energy inputs(8).

Another recent innovation in sludge digestion is a two-stage process in which the heat generated in an aerobic stage is used to attain the temperature needed for an anaerobic stage (9).

During the past year newspapers have described a new technology for oxidation of sludge and high-strength wastewaters using "ultraviolet light and the resultant effects from rapidly produced vacuums." The process refers to use of free radical oxidation and a controlled reaction chamber. The process is proprietary and has been applied on a small scale.

Land application has received a great deal of attention in recent years. The major applications are of municipal wastewaters after normal secondary treatment, so it is better described as advanced wastewater treatment. The harbinger of what may be significant increase in the use of land treatment is the application of raw or screened wastes to overland flow systems(10).

POTENTIAL SOURCES OF INNOVATION (BY ORGANIZATION)

Innovation in industrial wastewater treatment could conceivably be brought about by any one or combination of organizations, namely,

-- Manufacturers of wastewater treatment equipment;

-- Manufacturing industry producing wastewaters;

-- Government organizations, Federal and local.

I would like to make a few remarks about innovation by each of these.

Equipment Manufacturers

The wastewater equipment manufacturing industry deserves credit and praise for their innovation. They are typically eager to provide pilot equipment to test application potentials and give advice and help. Innovation and improvement is their life blood, and likely the creation of a superior product was the basis of their beginning.

These manufacturers face some significant handicaps as far as developing equipment specifically for industrial use is concerned, but these are not serious enough that something needs to be done about them. One of their handicaps is knowledge of the characteristics of the particular industrial waste. The Federal program of developing guidelines and limitations has made much of this information available in recent years. Manufacturing industry frequently has legitimate, rational reasons to limit access to their plants and their wastewater. A plant could be hanging onto its competitive viability by virtue of a small percent of the total costs. The reasons for caution include the potential of liability for accidents, loss of proprietary information on raw materials, loss of proprietary information on processes, administrative costs of interfacing with the researcher, fear of the unknown, and low likelihood of a helpful result. Therefore, anyone outside the industry is at a disadvantage in getting on his own initiative wastewater samples and information to work with.

Potential markets for treatment of a particular waste are often limited. A particular waste may have only six replicates in the U.S. How much development work can be done for six customers?

Another consideration is the financing of research and development costs. A member of the equipment manufacturing group has made a public statement that the industry is a low-profit industry. Therefore, the funds routinely available for research would not be great if this were universally true. The equipment manufacturers do not assemble data on sales or profits or annual research expenditures. I suppose this information could be obtained from the financial reports to stockholders, but I did not do this. Some information is available from other categories of industry. Figure 4 shows the basic research spending of chemical companies for a 15-year period. As a percent of sales over this period, basic research expenditures averaged about 0.3 percent. No figures are available on annual expenditures for industrial wastewater treatment plants, but figures are available for expenditures for municipal plants involved in the Federal Construction Grants Program. Over the last five years or so, this has been about five billion dollars a year. Let us assume that industries spend two billion dollars a year, for a total of seven billion dollars per year.

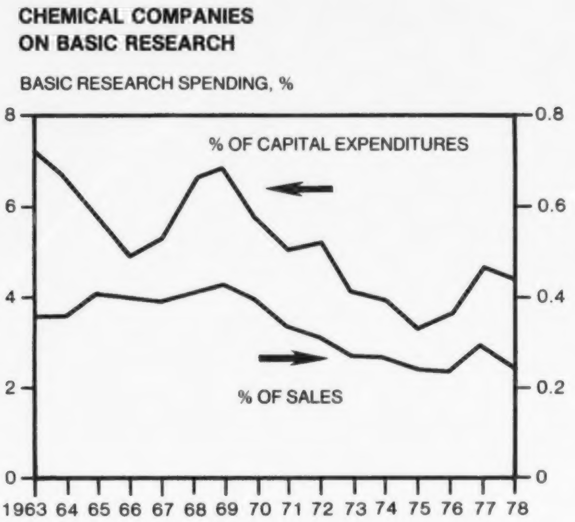
Thus at 0.3 percent this is $21 million per year for a parallel in basic research. According to the National Science, the all-industry cost of conducting research is about $75,000 per year per professional. Thus a 21 million dollar budget would correspond to a research force of 220 people. I hesitate to guess how many people are doing basic research in chemistry, physics, bacteriology related to environmental water quality maintenance, but I would say it is only a small fraction of 220.

Research and development effort in total, contrasted with basic research, is for some industries about ten times basic research expenditures, or 2+ percent of sales, Figure 5. The manufacturers of treatment equipment would only be involved in a portion of the total facility costs previously considered to be $ seven billion per year. Assuming $ three billion per year, an R&D expenditure at 2 percent would be $60 million per year. What are the equipment manufacturers actually spending? Maybe $5 million. Maybe less.

The claim I think that can be made is the research and development investment of the wastewater equipment industry is probably less than that which would be expected to yield a reasonable amount of innovation. The point in asserting this is to indicate that the industry has to have profits in order to generate ample and steady funds for research and development.

Manufacturing Industry

Manufacturing industries can be innovative themselves via their own technical resources in providing wastewater control and treatment. In-



Source: McGraw-Hill Economics Department

Figure 4. Basic research spending of chemical companies

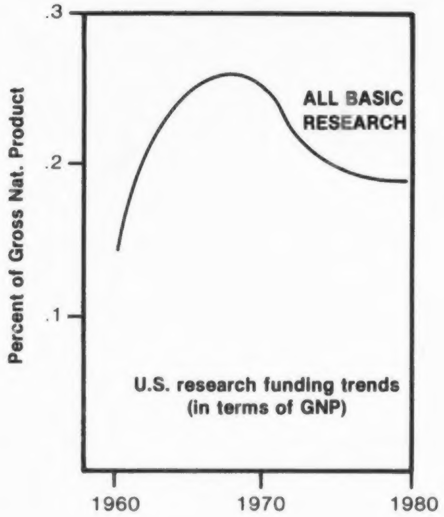


Figure 5. Research expenditures as percent of GNP

dustry, however, is sensitive to the assumption that regardless of the cost and technical complications of a law or regulation, good old innovative, resourceful industry can get the task done. This just is not a cardinal rule. The times for compliance permitted typically preclude a significant effort at innovation. Innovation in wastewater treatment is simply not their thing. Generally, they are not well-prepared or staffed for such activity.

Nevertheless, manufacturing industry has made some significant contributions to treatment technology. Dow Chemical Company has made numerous contributions. The company pioneered an application of biological treatment of wastes from chemical manufacturing, in underground injection, and in use of organic flocculating and dewatering agents. Not only did Dow pioneer biological treatment in general, but many modifications and refinements in biological treatment such as the trickling-filter-activated-sludge serial treatment, complete-mix-suspended-growth treatment, artificial surfaces for fixed-film treatment, and the suspended-growth circulation over tower systems. Union Carbide was responsible for application of the pure oxygen-suspended-growth biological systems and the aerobic-anaerobic phosphorus-removal process. DuPont, I believe, is currently marketing the 'PACT' process using powdered activated carbon. By way of innovation, a vegetable oil refiner has just published an exploratory investigation on the use of vegetable oil to extract certain priority pollutants from water. Relatively new is an extension and further development of the anaerobic, fixed-film-biological-treatment process for pretreatment by a chemical manufacturer.

So manufacturing industry has in the past and can be expected to provide some advances in the technology in the future. Frankly, I have no idea or inkling of what even the more immediate future will bring in absolutely new technology. It appears modifications of the anaerobic process, à la expanded bed media or rotating discs or a sludge blanket and special gas collection arrangements, may have application to treatment of strong industrial wastewaters produced at elevated temperatures.

Carmen Guarino, President of the Water Pollution Control Federation, has just this month suggested that media other than water be used for separating and carrying away impurities or contaminants. I presume he had in mind eliminating industrial water-borne wastes, not existing household systems in municipalities.

Incentive exists for inventing or applying manufacturing technology that inherently produces less wastewater. More likely, this advantage may be an unexpected bonus of a process development otherwise motivated, but nevertheless could weigh into the application of such a discovery. New manufacturing methodology with reduced wasteloads is more likely to be applied to new production facilities and not to conversions.

Much has been said and written of pollution control by means of finding use for materials discarded via wastewaters. This has great appeal. The 3M Company has actively disseminated this concept in recent years in its

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Pollution Prevention Pays program. Such resource conservation should always be given prime consideration. The world should not, however, expect great things from this concept. The sewers have been pretty well mined, but there will be new lodes if we remain alert.

I suspect that there will be some innovation in the application of new or existing technology to intermediate treatment of industrial wastewaters prior to discharge to POTW's. Lack of grant eligibility and unnecessarily high user charges, extra prefinancing charges, etc. will likely make such economically attractive. The newer anaerobic processes have already been used. Dispersed growth aeration and high-rate fixed film systems are other candidates.

High cost of treatment is also likely to make more common the segregation of concentrated wastes and their disposal other than to the sewer. Land spreading, land injection, land farming, and anaerobic treatment are some other avenues that will be used. I have a favorite idea, and that is to haul suitable organic concentrates and add them directly to municipal anaerobic digestors. Such concentrates, with as much as 20% biodegradable organics, could make a significant amount of methane for a city. The volume of wastes in typical cases, compared to municipal sludge, would be so small as to have no effect on sludge treatment capacity. If only those costs truly caused by such practice were applied to such use, I am sure the practice could save money over other disposal alternatives.

Government

The research activities of the Federal Government have contributed to the technology of industrial wastewater treatment to some extent, mainly through their contribution to municipal wastewater treatment. Government really has a difficult place in industrial waste technology research and development. It is awkward for a government to serve both as researcher regulator and enforcer.

If there is an unresolved problem in water quality and there is general welfare involvement, the Federal Government's participation in industrial waste technology research and development could be justified. For example, the new synthetic fuel program will likely meet such criteria. Some industries have used monies obtained from the Federal Research Grant programs in the past. The Government's role was predominantly in administering the funds and disseminating information developed. Recent trends in Government research is to have the work done by contractors. This paper cannot address the merits of grants, contracts, or direct research. My observation is that governmental people can do a more effective job of contract or grant supervision if such people have recent or ongoing participation in directly conducting research or development in their own laboratory and research facilities. A combination of doing work and supervising contracted or grant-supported work is a helpful productive strategy. The governmental person doing some work himself is much smarter in getting the Government's money's worth. The contractor has more respect for his counterpart. Therefore, I advocate some in-house effort in innovative research for wastewater treatment by the Federal Government where there is a general welfare interest and a recognized need.

There is one area that needs to be touched upon in relation to Government interest in technology, and that is the use of technology-based standards. There is possibly a force in the control strategy which is working against innovation for more effective treatment. This negative does not apply to energy saving innovations or toward any otherwise superior treatment which achieves the same degree of treatment that current technology does. Where technology available is the basis of control and is legislated universally, regardless of the need, the development of more effective technology may be considered a penalty, so the incentive to develop such is removed.

I feel compelled to speak to another subject of my interests. That is my earnest prayer of harmony among government, at all levels, and industry. I am awfully uncomfortable with the adversary relationship, particularly where it reaches the courts. The legislating carried on by the courts in the toxic pollutant settlement, the Milwaukee disaster, the pretreatment settlement, and others are low marks in the affairs of men. Reasonable technically knowledgeable people should have been able to avoid such costly affairs.

Honesty, openness and full cooperation among the Federal Government, government at other levels, and industry is the answer, in my opinion. The answer is defining real problems, reaching accord on control requirements, and getting the job done. This includes getting it done with less use of energy and at less other costs of money and energy through use of innovative technology. The advances that have occurred in the past have resulted, to a significant extent, from cooperative efforts from all interests. The Government has played a significant role in this progress.

"As a matter of principle, technological innovation should be the job of innovators--namely businesses themselves." This statement is not original with me but I endorse it. The statement is from a document on economic planning by the Japanese Government, 1980.

Much has been said of late about the current business-government relationship in the United States. People speak admirably of the perceived situation in Japan where cooperation and mutual support prevails rather than antagonism. My pitch echoes this endorsement. Recently Edward Donley, Chief Executive Officer of Air Products, in a public statement expressed concern that government, academia, and industry have not worked well together. He says, "Adversarial relationships between government and industry and academia are counterproductive" (11). Donley points out that in the 1930's when the country was in desperate trouble and Franklin Roosevelt was forging a new coalition, he attacked business and called businessmen "Economic Royalists." Perhaps that contorted view has never left us. Even Roosevelt, when the war came, changed his tune from "Economic Royalists" to "the arsenal of democracy." We need such cooperation again.

Local government's part in innovation must not be neglected. Los Angeles County Sanitary Districts, Chicago, and even New York City have made innovative contributions. No one could advocate a large budget for research and development at any but the very large municipalities. The smaller places would not be expected to contribute much. Yet cities like Midland, Michigan, have engineers like A. Maass who conceived and proved out a process innovation. Perhaps the answer for smaller cities is a pooling of their funds for support of their research, innovation, and development organization. Perhaps some organization like the Water Pollution Control Federation could be the agent for such activity.

BRINGING ABOUT INNOVATION

What does experience teach us about what brings about successful research and innovation? Is there some objective, scientific proven technique? Is there something stronger than illustrations of how certain particular things happened? Of the many things that have been done to stimulate research and innovation, which worked best? The Department of Defense sponsored a project in 1966 to analyze how 20 important weapons came to be developed(12). Some of the conclusions were:

1. The contributions of university research were minimal.
2. Scientists contributed most effectively when their effort was mission oriented.
3. The lag in application was shortest when work was area-targeted by the sponsor.

Medical and other scientists countered with illustrations of the important contributions of basic, fundamental, undirected, non-targeted research.

Recently a profound study of several years' duration was reported which analyzed how and why lifesaving advances have come about in one readily defined area of medical research(13). That area was cardiovascular and pulmonary diseases. More than 4,000 scientific articles were screened and 529 were analyzed. The analysis showed:

41 percent of the essential work for clinical advance was not clinically oriented at the time it was done.

61.7 percent was basic research.

15.3 percent was concerned with development of new apparatus, techniques, operations or procedures.

What does this research on research tell us?

To me it says that basic research is the major source of advancement on problems--knowledge for knowledge's sake gets most of the pots of gold at the end of the rainbow. However, 15.3 percent were in the development portion of the research world. That 15 percent may be the innovation we are addressing; a small but significant part of the effort. Perhaps the giant strides will come from basic physics, chemistry, or biology which we engineers can't comprehend at the moment, really basic research.

I hope I am allowed a few remarks addressing innovation in its broad application and not just related to industrial wastewater treatment. I would like to impose on the audience my thoughts on societal structure which would promote discovery, invention, and innovation to a greater extent than our present system does. I feel certain that our system of valuing and regarding the technology innovator, inventor, researcher is not optimal for promoting maximum achievement in these areas. I think my observations are supported by the surge of national support and surge of achievement in science that occurred following the space program of the 1950's. We have lost that fervor for science. I think that endeavor of the 1950's raised societal regards for scientists in all fields, attracted minds otherwise likely to train for other things, and informed the public sufficiently that they supported such use of moneys.

If we accept the concept that human minds with greater potential of scientific achievement can be uncovered, nurtured, motivated, and utilized, then the societal system ought to do just that to maximize scientific achievement. I contend that our present societal system does not do that optimally.

Our young humans with strong and singular scientific bent are ostracized, scorned and, at best, poorly honored in our typical school.

Please forgive my crude concept of motivation, but I believe that people pursue goals more vigorously where the objective is one or a combination of the following:

--To be somebody;
--To make a great contribution and be recognized for it;
--To make a great amount of money.

I doubt that pursuit of education in technology or science would occur to many people as a means of accomplishing any of these in our present society. In the employment world it is difficult to stroke and reward the scientific genius because he sees success as proceeding up some hierarchy of organization. So even those inventive minds which do find their way into the system are motivated to administration, and an innovator would become too remote to contribute.

The scientific or technological innovator is infrequently found in lists of:

--Those with large fortunes,
--Those singled out for historical attention,
--Those of news interest,

and in the mundane world:

--Those who are members of the club, be it country, social, or local decision-makers or of generally recognized achievers.

The scientist or engineer does not enjoy the professional status of members of the medical profession or the legal profession or the accounting profession or the titles that come with careers in business. There must be a better way.

I do not wish to be so foolish and vain to propose how this could be corrected. I have confidence that society can be led to create a better system for scientific and technical rewards and in societal recognition of technical innovators.

I do not think it is practical to upgrade the image or name of the engineer. In fact, I think the engineer category might better be liberalized in one respect. The insistence on certain ability with complex math turns many people from the profession. For the preponderance of engineers, their involvement in the more complex mathematics ends in school. Thus I think the engineer shortage would be largely solved by eliminating or playing down the higher mathematics involvement.

Engineers could then continue to contribute as per normal principally regarding application of acquired knowledge and experience. Far be it from me to detract from the engineering profession that exists. But it won't stretch to fit the profession I am talking about. The word has been too corrupted and just cannot serve the variation in meaning needed.

The new profession I would create would have a new name and a new educational goal. Articles in publications such as those of the American Association for the Advancement of Science have used the professional designation of engineer-scientist. The idea is good but the name is too clumsy. How do you like Tekreator (Technical Creator) or Techner (Technical Innovator)? What's your suggestion?

Academic preparation and multi-science requirements would be like other professions, with more extensive academic training and admission via certifying boards.

INHIBITORS OF INNOVATION

The innovation accomplished to date in wastewater treatment seems to take an inordinate amount of time. The wastewater treatment processes are not unique in this regard. Perhaps the attention to innovative technology brought about by the Clean Water Act will serve a useful purpose, if only in speeding up the use of a good idea. Even after reasonable development and dissemination of information, the time period before wide use can be long. This can be laid to some of the following causes.

-- General resistance to change;

-- Ignorance of the existence of the new invention;

-- Misconceptions from early glitches in development;

-- Avoidance of chancing failure, either as a monetary or reputation damage matter;

-- Societal attitudes and actions which either purposely or inadvertently reject new concepts.

J. W. Fead, a Civil Engineer, recently wrote on this latter subject. He stated:

> "The political and economic environment of the United States almost precludes the use of daring and innovation in civil engineering designs. The current climate of litigation and professional liability make it almost suicidal for a design professional to use innovative alternatives to "tried and true" methods. The more innovative the method, the truer this is. If a lawsuit arises and the designer has not used standard practices, he runs a great risk of losing no matter how sound the design might have been. Lawsuits are seldom, if ever, decided upon technical merit."

Other engineers are less inhibited by the reputation and liability factors of lack of success and indeed a few may encourage a reputation of new approaches and new ideas to attract clients.

Certainly we must work for conditions which allow use of new reasonably tested technology without dire consequences to the user in event of failure.

THE FUTURE

Attention to innovation in these times is likely to focus on energy. This is good. However, some potential may lie elsewhere. Where? Labor and administration perhaps? Quite likely labor and administration will total more on the OM&R budget than any other item. Administration can be pretty fat depending on how much the Engineering Department, Manager, Personnel Office, Accounting Department, Legal Department, Purchasing Department, etc. is allotted to the wastewater budget. Considering municipal systems, I have heard of the meter-reading bill mailing and related costs running over one dollar per month. A typical monthly household bill is $6 to $10 per month. Some innovation here has the potential of up to a 15 percent savings.

Another potential is manpower use. Manpower use in treating community wastes and in industrial point source plants is a big mystery to me. I see items on budgets of $500,000 for operation and $300,000 for maintenance. Operation is of pumps or screens or compressors, I presume. Maintenance is repair of same. What does an operator operate while a repairman repairs? Why not operator and repairman being one and the same? At any rate, there is no standard to compare any manpower use to. Automobile competitors talk in terms of cars produced per man year--be it 20 or 35. Would it promote innovation in manpower use to publish each year a treatment plant's production in million gallons of treated wastewater production per man year? What would Cincinnatians say about a wastewater manpower use 60 percent of Columbus', or Cleveland's or Louisville's, or DuPont's being 160 percent of Dow's?

Automation might play a role in manpower reduction. Newer plants have a great deal of automation, computer controlled systems, etc. Do they save manpower? Who knows! There is no standard to gauge by.

We have seen some trend toward plant operation by contract. How do the costs compare per unit of production? I see a place for a compromise, namely that of contracting for maintenance and repair only. Perhaps competition could make great gains here. You may ask how do industries' treatment costs compare among themselves? How do they minimize labor costs, etc.? Information of this sort is part of any industry's competitive position and, therefore, is frequently maintained as private as possible. So we are no help either. Industries, much to their credit, do share a remarkable amount of information on environmental control. I have never known of any innovation or development in wastewater treatment being withheld.

Before closing I wish that I could express or present some predictions of great strides in forthcoming technology. I am optimistic that there will be some incremental advances at least but I cannot give you thoughts about such that would blow your minds. The innovations that I see out there coming along are rather prosaic:

- Anaerobic treatment, more likely pretreatment, for hot high strength organic industrial wastes.
- Application of processes of intermediate efficiency for pretreatment.
- Land spreading or land injection of concentrates.

Let me end on an optimistic note by again quoting Mr. Donley, Chief Executive Officer for Air Products and Chemicals. "The next one or two decades," he says, "will see a golden age of invention. Every design is for economic conditions that no longer exist. Our system is based on cheap energy. We need a plethora of inventions and innovations."

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INDUSTRIAL WASTEWATER POLLUTION CONTROL TECHNOLOGY - FUTURE TRENDS

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In recent years, the major emphasis in wastewater treatment has shifted from the removal of conventional pollutants (BOD and suspended solids) to a variety of other pollutants. Removal of nitrogen and phosphorus is a requirement in many parts of the United States and Canada. Through recent Federal legislation, removal of priority pollutants to low residual levels will soon be required of all industrial discharges. Priority pollutants include a variety of heavy metals and toxic organics. In order to achieve these objectives in a cost-effective manner, a new approach to water quality management is needed. In the early 1970's the technology employed add-on end-of-pipe processes including coagulation, filtration, and granular carbon adsorption. An economic analysis should examine costs for the benefits achieved for residual pollutant removal. Emphasis at present is being directed toward in-plant control technology or modifications to existing conventional technology.

Source Control

In most cases, source control will involve process changes or chemical substitutions to eliminate specific priority pollutants or pretreatment of the discharges containing those pollutants. Alternative technologies are shown in Figure 1. Source control of heavy metals can be achieved by precipitation with lime, sulfide, and in some cases, co-precipitation with alum or iron salts. A pretreatment is required in cases where the metals are complexed. If a high removal of the total metal is required, filtration, following precipitation and sedimentation may be required. In some cases, ion exchange will be a cost-effective alternative. This is particularly true in cases where metal recovery is economically achievable. Organic removal can be achieved by chemical oxidation with ozone or catalyzed hydrogen peroxide, by adsorption on granular activated carbon or macroreticular resins, or in the case of volatile constituents, stripping with air or steam. Under practical conditions, complete degradation of fairly reactive compounds such as saturated hydrocarbons and halogenated aliphatic compounds does not occur with ozone alone, but current research has shown that ozone with an additional energy source, i.e., sonification, ultraviolet radiation,or a catalyst, will readily decompose many refractory compounds. In many cases complete oxidation of complex organics with ozone is very expensive. However, partial chemical oxidation with ozone will frequently modify the molecular structure rendering it more biodegradable in subsequent treatment processes. For example, Yocum et al showed that the BOD_5/TOC ratio increased from 0.11 to 0.98 following ozonation in polyol wastewater (1).

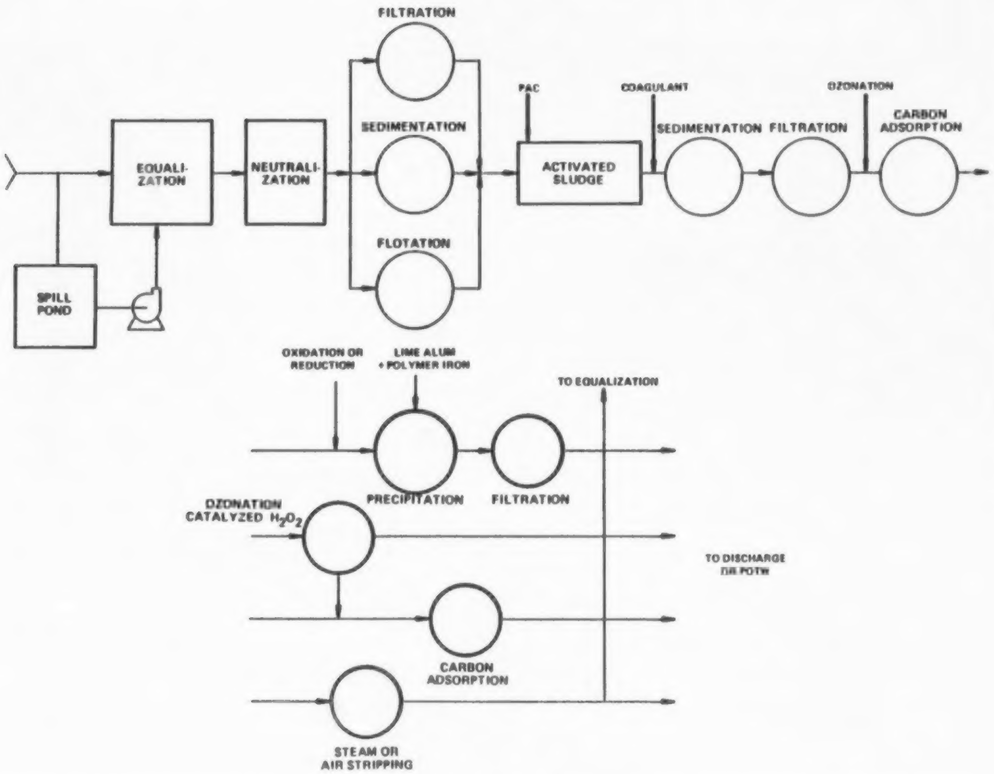
FILTRATION
SEDIMENTATION
FLOTATION
EQUALI-ZATION
NEUTRALI-ZATION
SPILL POND
PAC
ACTIVATED SLUDGE
COAGULANT
SEDIMENTATION
FILTRATION
OZONATION
CARBON ADSORPTION
OXIDATION OR REDUCTION
LIME ALUM + POLYMER IRON
TO EQUALIZATION
PRECIPITATION
FILTRATION
OZONATION CATALYZED H_2O_2
TO DISCHARGE OR POTW
CARBON ADSORPTION
STEAM OR AIR STRIPPING

Figure 1. Alternative Technologies for Removal of Priority Pollutants

Pretreatment

In order to meet future effluent limitations, improved pretreatment will be required in many cases. Pretreatment should minimize variation in wastewater loading and remove pollutants which interfere with the biological process operation or pass through the system such as oil and heavy metals. Pretreatment should therefore consider improved equalization and more effective removal of noncompatible pollutants such as oil, sulfides, heavy metals, and inhibitory organics. It has been found in a number of cases that the removal of inhibitory organics can markedly improve the performance of the activated sludge process. An example of this for a POTW treating a mixture of municipal and industrial wastewaters is shown in Table 1. As shown, pretreatment of a pesticide wastewater markedly improved the reaction rate of the combined wastewater mixture.

Table 1. Biological reaction rate coefficients with and without carbon pretreatment of a pesticide wastewater

	Non-Carbon Treated K	Carbon Treated K
28°C	2.25	23.1
8°C	0.81	6.5

Biological Wastewater Treatment

As we enter the 1980's most industry will have a biological wastewater treatment plant in place and therefore considerations of upgraded effluent quality will usually start from this baseline. Low energy consuming systems such as anaerobic processes, trickling filters and RBC's will find increased use where applicable. These processes should find particular application where increased organic loadings require expansion of the biological oxidation facility. The biological pretreatment should result in considerable energy conservation. For complex wastewaters, the pretreatment process will remove the more readily degradable organics resulting in a reduction in the reaction rate in the activated sludge process. The net effect may be a less than expected reduction in secondary aeration volume.

In a well-designed and operated municipal activated sludge plant, effluent suspended solids are rarely a problem. Settleable solids in the range of 20-30 mg/l are readily achievable. In the treatment of soluble industrial wastewaters however, there are several factors which will drastically affect the effluent suspended solids. In addition, this increase in effluent suspended solids is usually dispersed and non-settleable.

The factors which relate to effluent suspended solids are temperature, dissolved inorganic solids and surface tension.

It has been observed that the effluent suspended solids will increase as the temperature decreases. For example, the effluent suspended solids during summer operation at the Union Carbide plant in South Charleston, West Virginia, averaged 42 mg/l and 104 mg/l during winter operation. An increase in total dissolved solids will usually cause an increase in effluent suspended solids. In most cases these solids have been identified as dispersed bacteria. Results from an organic chemicals wastewater are shown in Figure 2. A statistical evaluation of plant operating data at a de-inking mill showed that increased surfactant usage within the mill resulted in an increase in effluent suspended solids.

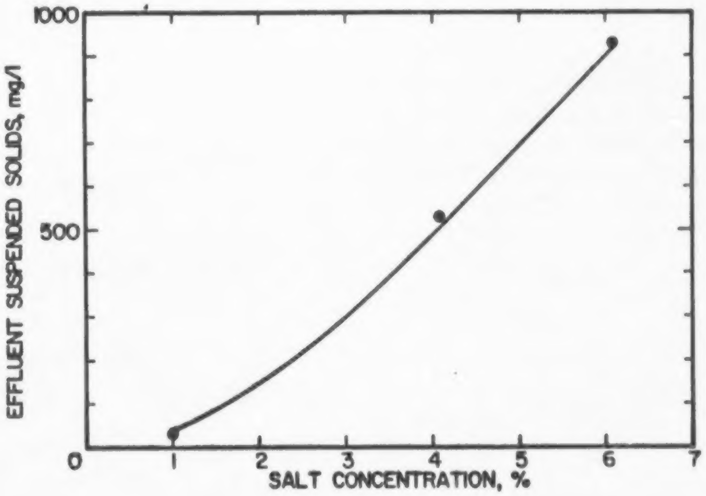

Figure 2. Effect of Inorganic Salt Concentration on Effluent Suspended Solids

Most effluent discharge permits in the United States require effluent suspended solids of less than 40 mg/l. In order to meet these requirements coagulation is required for solids removal. Present practice involves the addition of the coagulant prior to the final clarifier. Common coagulants include cationic polyelectrolytes, alum or iron salts. If high dosages of alum or iron are required, the increased costs of sludge handling favors the use of polymers. It is apparent that minimizing heat losses in the biological process is an important economic consideration for effluent suspended solids control. Approaches include the use of subsurface aerators rather than surface aerators, and the injection of waste steam to the aeration basins.

High temperature will also cause operating problems. In a recent study the aeration basin temperature was varied from 95°F to 125°F (2). This resulted in a marked deterioration in sludge settling properties. The protozoan population disappeared above a temperature of 105°F and biological flocculation deteriorated as evidenced by the decrease in zone settling velocity as shown in Figure 3.

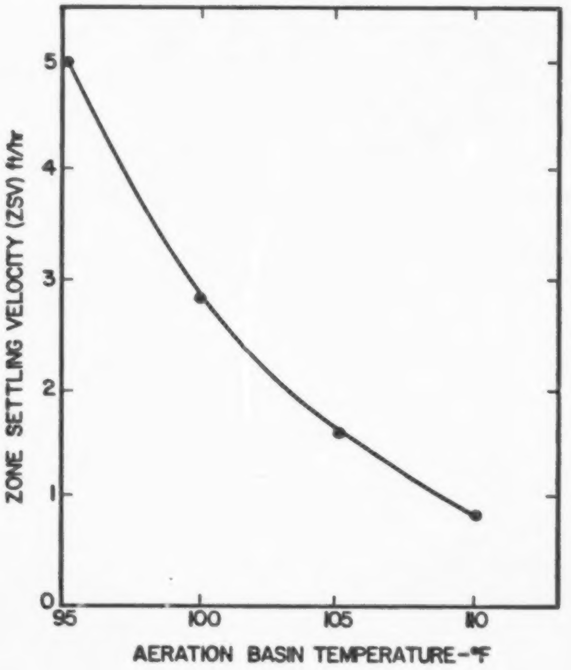

Figure 3. Zone Settling Velocity as a Function of Temperature at a MLSS Concentration of 5,000 mg/l

Priority Pollutants

Recently the U.S. EPA defined a variety of toxic organics and heavy metals as priority pollutants which must be removed from effluents prior to discharge to water courses. Investigations have been conducted to define the fate of these pollutants in conventional biological wastewater treatment plants. In general, removal by existing technology is more cost-effective than preremoval or add-on technology.

A recent study has shown that many of the organic priority pollutants are removed to low residual levels in the activated sludge process(3). Results from a petroleum refinery are summarized in Table 2.

Table 2. Removal of priority pollutants by the activated sludge process

Compound Class	Concentration (ppb)	Average Percent Removal by Activated Sludge
Alkanes	11 - 683	99.65
Cycloalkanes	21 - 71	99.81
Alkylated Benzenes	5 - 187	99.97
Tetralins	11 - 104	99.98
Alkylated Naphthalenes	21 - 448	99.93
Alkylated Benzothiophenes and Dibenzothiophenes	8 - 32	99.88
Alkylated PNA's	3 - 168	99.86

It is significant to note that priority pollutant removal in the activated sludge process can occur by three mechanisms, namely, stripping, adsorption to the biological floc, or biological degradation. In the case of biodegradation, little is known of degradation by-products, if any. Accumulation of these materials in the sludge would cause problems relative to sludge disposal alternatives.

Several factors need to be considered in the removal of priority pollutants in biological systems. In some cases long acclimation periods are required.

Investigations must also be made to ensure that oxidation byproducts are not toxic. Winter operation needs to be considered since the degradation rate is a function of basin temperature. It has also been shown in a number of cases that inhibition is increased at decreasing operating temperatures.

Recent emphasis on improved organic removal particularly refractory organics and priority pollutants has led to the application of powdered activated carbon (PAC) to the activated sludge process (PACT®). In several industrial catagories in the United States, EPA has defined PAC as the basis for future water quality standards.

Investigation of PAC systems have centered around several process enhancement subjects. These include the enhancement of a system to receive shock loads or temperature changes, improved non-biodegradable organics removal, improved removal of priority pollutants, improved color removal, enhancing nitrification, and the resistance to biologically toxic or static substances, improving the hydraulic capacity of existing systems, suppressing foaming, improving sludge handling, and reducing sludge bulking.

The effect of PAC addition on effluent COD and suspended solids to an activated sludge plant treating a petroleum refinery wastewater is shown in Figure 4. Considerable data have been developed on the application of PAC in the chemical and petroleum refinery industries. Considerable improvement was observed in the overall variability in effluent COD and suspended solids as well as the median levels. Improvement in the removal of priority pollutants is shown in Table 3.

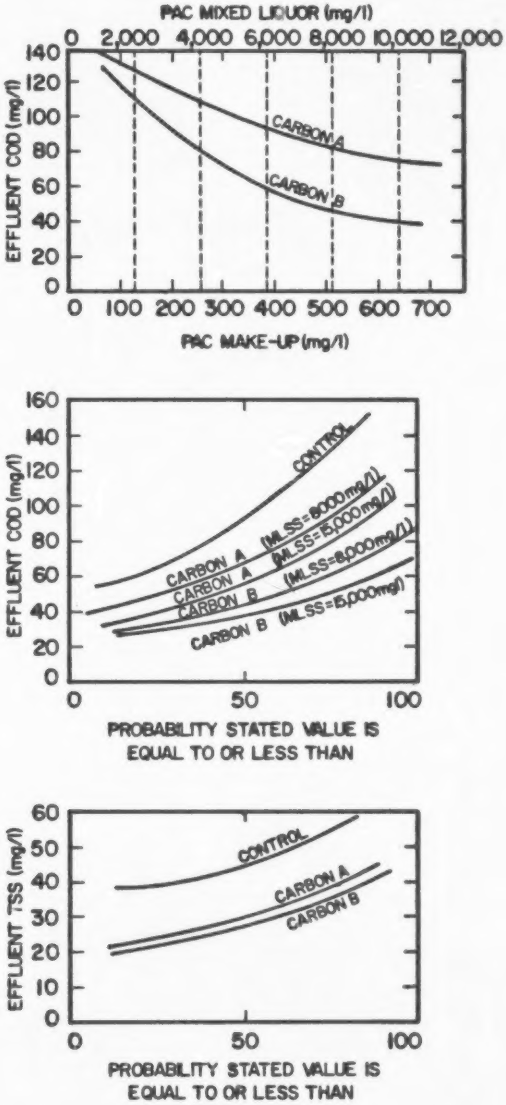

Figure 4. Conceptual PAC Relationship

Table 3. Comparison of PACT® and activated sludge for organics removal

Organic	Effluent Concentration (mg/l) PACT®	Effluent Concentration (mg/l) Activated Sludge
Chlorinated Pesticides	0.017	0.35
Organo-sulfur Pesticides	0	15.0
Organo-phosphate Pesticides	1.23	3.03
PCB's	0.008	0.13

Enhancement of nitrification in industrial wastewaters using PAC has been demonstrated. Nitrification has not been successful in coke plant wastewaters. Inhibition has been attributed to some specific organics initially present in the wastewater or intermediate products of bio-oxidation. Addition of PAC resulted in complete nitrification (4). Low carbon dosages permitted nitrite formation but still inhibited *Nitrobacter* while higher PAC dosages eliminated inhibition of the *Nitrobacter*. Results are summarized in Table 4.

Table 4. Effect of PAC on nitrification of coke plant wastewaters

PAC feed mg/l	SRT * days	TOC mg/l	TKN ** mg/l	NH_3-N mg/l	NO_2-N mg/l	NO_3-N mg/l
0	40	31	72	68	4.0	0
33	30	20	6.3	1	4.0	9.0
50	40	26	6.4	1	1.0	13.0

Influent conditions: TOC=535 mg/l, TKN=155 mg/l, NH_3-N=80 mg/l.

*-SRT-Sludge Retention Time **-TKN-Total Kjeldahl Nitrogen

ECONOMICS OF ADVANCED WASTEWATER TREATMENT

No discussion of future trends in industrial wastewater treatment technology would be complete without consideration of economics. Rapid escalation in the cost of energy and chemicals have placed emphasis on technologies which are cost-effective in these areas. This includes in-plant modification, water reuse and by-product recovery and modifications to existing technologies. As an example, a comprehensive study was made on an organic chemicals plant to define the most cost-effective approach to meet future effluent limitations (5). It was shown that maximum inplant modification would result in a 25 percent reduction in wastewater flow and a 34 percent reduction in organic loading. This, combined with the addition of chemical coagulation and filtration, results in an effluent COD level of 22,500 lbs per day at an annual cost of 1.33 million dollars. End-of-pipe granular carbon adsorption to the existing facility would result in an effluent COD level of 17,850 lbs per day at an annual cost of 4.1 million dollars. The economic advantages, inplant changes, and modifications to the existing technology are obvious.

Ford and Tischler developed the economics of advanced wastewater treatment for the petroleum refining industry (6). In comparing the cost-effectiveness of granular vs. powdered activated carbon, Tischler and Ford showed a cost of \$2.02/lb COD removed for PAC and a cost of \$3.79/lb COD removed for granular carbon (6). An evaluation of energy requirements for advanced wastewater treatment in the petroleum refining industry was also favorable for PAC over GAC.

It is recognized that cost-effectiveness will vary with industrial category depending on the concentration and characteristics of the pollutants to be removed. In most cases, however, considerations of energy and chemical usage will mitigate against end-of-pipe treatment, whereas large volumes of wastewater at low pollutant concentrations must be considered for treatment.

SUMMARY

Industry today is faced with increasingly stringent effluent requirements. At the same time the cost of energy and chemicals is rising at unprecedented rates. In order to develop cost-effective solutions to future industrial wastewater treatment, innovative approaches are required. In most cases this will involve pollutant control at the source and modifications to existing and conventional pollution control technology. This paper discusses present trends in those areas and some of the economic implications involved. The most cost-effective solution for a specific industry will depend on the characteristics of the wastewater generated and the effluent quality requirements.

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INNOVATIVE INDUSTRIAL WASTEWATER TECHNOLOGY

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INTRODUCTION

Innovative technology may apply to the control of newly identified pollutants and to more effective or less costly alternatives to present control technology. Current innovative technology developments that will be applied over the next 5 to 10 years include more efficient processes to control or remove BOD, nonbiodegradable organics, color, and ammonia.

Residual disposal is an increasing challenge. Innovation in conditioning residuals and developing animal feeds from biological sludges are now being demonstrated.

In the coming years, intensive, innovative water and wastewater management will play an increasing role in pollution control. Innovations in the design of boilers, cooling towers, evaporators, and brine concentrators are examples of process support equipment which will allow more water reuse and less discharge of pollutants per unit of production.

The following paragraphs present general descriptions of selected innovative technologies which we believe have promise of providing for less costly and more effective wastewater treatment.

INNOVATIVE TECHNOLOGIES

Anaerobic Systems

Anaerobic filters, as applied to the protein-rich wheat starch plant wastewater at Centennial Mills in 1971, offer a low-cost, effective BOD removal system for pretreatment of soluble, biodegradable wastewaters. Anaerobic contactors and fluidized bed systems also offer these same benefits.

In addition to the limited full-scale application of anaerobic systems over the past few years, several pilot plants and demonstration projects are presently underway. Recently, Celanese Corporation applied for patents for an anaerobic filter system in the United States. In our view, the development of anaerobic systems has been slow because of a lack of interest by wastewater equipment companies and the time required to perform laboratory and pilot plant simulations with anaerobic systems.

Powdered Activated Carbon

The use of powdered activated carbon has great promise for both removal of BOD and more complex organics. The availability of this process in several variations has been well reported in the literature; however, we believe that there are many potential future applications for industrial wastewaters.

Ammonia Removal Systems

Several of the innovations in removable ammonia technology include recovery of ammonia as a gas or salt. The system developed and applied by CH2M HILL includes gas stripping and acid absorption of ammonia. The ion exchange material which has been used as part of the ammonia removal system when treating waste with low concentrations of ammonia is a natural zeolite, clinoptilolite. Although these systems have not been applied to industrial wastewaters in full scale, they have been pilot tested. These processes have been applied to domestic sewage at the Tahoe-Truckee Sanitation Authority Plant in California and the Upper Occoquan Sewage Authority Plant in Fairfax County, Virginia. The recovered ammonia sulfate will be sold to a commercial distributor.

Zimpro is marketing an ammonia removal process (ARP) system which uses a stripper and an absorber. In addition, it includes a step for regenerating the acid used in the absorber and produces a 30-percent aqueous ammonia solution.

Color Removal

In spite of the uncertainty concerning the need or requirement for color removal, several processes have been developed for pulp and papermill wastewater. However, the high cost of these processes are of great concern. This concern led International Paper Company to retain CH2M HILL to study and pilot the application of a color removal system using magnesium carbonate. CH2M HILL previously developed this process for domestic water coagulation and softening. The pilot plant studies on color removal from pulp and papermill caustic extracts are very encouraging. The developments resulting from these studies are the property of International Paper Company. The company is interested in marketing the technology.

Vertical Tube Reactor

The system being developed by VTR Incorporated of Denver, Colorado, uses a deep-well configuration (5000± feet) to induce the conditions necessary for wet oxidation. The reactions which occur are similar to those of the Zimpro process. The apparent best applications for this unit process are high-strength wastewater or residuals. The system has the capability to produce usable energy from the reaction. It is an innovative configuration which should have many applications.

ANIMAL FEED PRODUCTION

Many industrial residuals have the potential to be used as animal feed. In instances where ammonia removal from meat processing wastes is necessary, the lignosulfonic acid (LSA) system should prove to be economically attractive. This system has the capability to reduce BOD, suspended solids and ammonia by coagulation and floatation. The recovered product is a high-protein animal feed. To our knowledge, there is only one of these systems presently in operation in the United States. It is located at the Sterling Beef Company in Sterling, Colorado.

The Adolph Coors Brewing Company of Golden, Colorado, is using a Carver-Greenfield system to condition and dewater waste-activated sludge from their industrial wastewater treatment plant so that it can be marketed as cattlefeed.

CH2M HILL has studied insiling waste-activated sludge with other animal feed materials. This process, under some conditions appears promising.

In the future it will likely be more common to disinfect industrial residuals for use as a feed. A disinfection process now under development by Sandia National Laboratories of Albuquerque, New Mexico, uses Cesium-137 as a gamma ray irradiation source. This is an innovative application of a byproduct from the nuclear program. This system is currently available for commercial application.

FUTURE INNOVATIVE TECHNOLOGY

Future innovations will result from increased understanding of biological systems as applied to industrial wastewaters. We anticipate developments in anaerobic and facultative biological systems. Added innovation will result from new ion exchange materials, improved reverse osmosis membranes, and modified industrial process equipment such as evaporators, incinerators, cooling towers, and brine concentrators.

Incineration of volatile pollutants which cannot be recovered for beneficial or at least a benign use will be one, and perhaps the only, disposal option. Therefore, innovations in incinerators, especially those designed for the destruction of volatile pollutants, will be essential.

STRUCTURE FOR INNOVATION

In the United States we have taken great pride in our ability to be innovative. Innovation in the world of consumer products has resulted in rewards for companies and individuals who correctly identify and satisfy real consumer needs. A majority of the examples that come to mind resulted from developing, financing, producing, and marketing an innovative idea within one company or a group of organizations with common and compatible goals. This is in contrast to the general field of industrial wastewater innovation where the elements necessary for innovation are often diffused among several organizations (universities, consultants, agencies, manufacturers, etc.) that have different goals and that do not have the ability to carry an innovative idea through the many stages necessary for its application and resulting rewards.

A great deal of industrial wastewater innovation has occurred and will continue to occur. However, the rate could be accelerated if more of the structure and benefits distribution could be modified to parallel more closely that now common to the consumer products industry.

INNOVATION IN THE ENVIRONMENTAL TECHNOLOGY INDUSTRY
INPLANT CONTROLS AND PROCESS MODIFICATION

John H. Robertson, Vice President-Hazardous Wastes Management
International Incinerators, Inc.

INTRODUCTION

The emphasis in industrial wastewater control is shifting today, away from the concern over the traditional pollutants to the control of specific organic chemicals and heavy metals. EPA has defined the pollutants of concern as 129 "priority pollutants," and regulations governing the permissible levels of discharge of these materials will be published soon as effluent guidelines for 33 industrial categories.

Most of these priority pollutants are complex organic compounds which are not easily degraded in conventional wastewater treatment plants and, at some concentrations, can be toxic to biological systems. For these reasons, treatment and control approaches other than the conventional systems employed in the past will be required regardless of whether industry treats its own wastes onsite, or discharges to a municipal facility.

DEFINITION OF THE PROBLEM

The key to proper control of industrial wastes has always been the proper definition of the problem, and the future will make this key even more significant. Priority pollutants are generally present in wastewaters only in small concentrations, and can be very low in concentration after wastes from several sources are mixed together in the plant sewer system. Removal of these low concentrations is very difficult. Also, most treatment approaches are specific to certain types of compounds, and it is far more difficult to provide a cost-effective solution for a broad mixture of pollutants than for higher concentrations of a few pollutants. These factors all lead toward:

1) Identifying and understanding the source and mode of generation of the pollutants

2) Isolating waste streams containing the priority pollutants

3) Control at or near the source of the identified pollutants, to take advantage of the most concentrated and controllable waste streams.

Assuming that the pollutants which require control in the plant effluent have been identified, then a secondary survey to identify the sources of each pollutant is required. The objective of this survey should be to find the offending pollutants in their most concentrated form, as free as possible from problems generated by other interfering substances. At the same time, the survey should yield information on the manner in which each of the pollutants is generated. When the survey results are available, they should be checked against your knowledge of the process itself, to determine if the pollutant is: a raw material; an intermediate; the product; or a byproduct.

DETERMINE THE CONTROL PROGRAM

With the basic problem defined, determination of the best methods of control can begin. In general, if a pollutant or pollutants are wide spread throughout the plant, then centralized treatment or additions to end-of-pipe treatment will usually be attractive. If a pollutant is localized at a process, then one of the inplant alternatives will be most effective. Alternatives for control should be examined in the following priority:

1) Process changes to increase efficiency

2) Recovery for reuse onsite

3) Recovery in a form to be sold (or even given away) for reprocessing by others

4) Recovery or isolation for destruction

5) Additions to end-of-pipe techniques

6) Conversion to a byproduct through end-of-pipe treatment methods.

These elements are listed in the order of their usual cost-effectiveness It should be noted that elements 1, 2, and 5 provide total control by the generating industry. The other three approaches may or do pass the ultimate control on to others, unless the generating industry is large enough to have total byproduct control technically and economically feasible as an onsite portion of the control system.

REVIEW OF ALTERNATIVE APPROACHES

1) Process Modifications

The first priority in any evaluation of at-source control should always be to take maximum advantage of the equipment already in place - the process plant itself. Once the priority pollutant has been identified as to point of generation and amount, every attempt should be made to reduce or eliminate it through process modifications.

Considerable care must be taken in reliance on this approach alone, however. If the modification consists of a sophisticated manipulation of operating controls or responses, its effect may not be sustainable by the regular operating staff. To be effective, the modifications must be as positive and reliable as the original operating mode.

Spills, leaks, and other fugitive pollutant sources can be very significant when microgram concentrations are required by regulations. Only 1 lb of an organic in 1 million gal of water equals 0.12 ppm, about 10 times the probable needed control level. Housekeeping and control of miscellaneous waste sources will always be of prime importance in control of priority pollutants.

It is difficult to hold a production unit responsible for eliminating or minimizing waste generation unless regular monitoring of the pollutants to be controlled, or if an effective surrogate is employed in the same frequency and manner of other operating controls. Plans and budgets for process modifications (or any inplant control measures) should include an appropriate waste-sampling station and analytical procedures.

Whenever contemplating a new plant, or adding a new process to an old plant, the production facilities should be designed to minimize waste generation. The company's research departments must develop process routes to products which do not create new problems in treatment or control. It is always less expensive to design proper controls into a process when it is built, than to try to retrofit after the process is in operation.

To provide the proper incentive for researchers and decisionmakers, it is essential that the true costs of waste treatment and control be identified and equitably allocated to each contributing source, and those allocated costs be disclosed to those responsible for the decisions regarding the process design. Without a proper factoring of waste generation upon the costs of treatment and control, it is quite likely that process design decisions may never reach the level of waste generation cognizance that they should.

In a few cases, waste generation from a given source may be high enough and complex enough that the most effective control measure may be a rebuilding of the process equipment. To determine the cost-effectiveness of such a drastic measure, again the true costs of waste treatment must be known in order to compare the available alternatives.

2) Inplant Treatment and Control

Treating priority pollutants at or near their source of generation offers the best technical and economic opportunities. The pollutant is at its most concentrated level and in its most isolated form, that is, free of possible interferences to treatment from pollutants from other sources. Many unit processes that are not technically possible on a more dilute waste can be considered for inplant applications.

If process modifications are not possible, or if they still leave pollutant levels too high, then some type of external control procedures are required. In examining these alternatives, a priority of desirability exists. In most alternatives, the pollutant will still be in a form too dilute to be of value, and recovery from the wastewater is a required first step. Once it is recovered, a decision has to be made regarding disposition.

Reuse directly in the process has the advantages of cost recovery and total control within the process unit. Use by another process in the same plant has essentially the same advantages, but spreads the control. Sale to an outside company has cost-recovery advantages, but control risks are higher in transportation and passing control to others. Admittedly, these risks are no different from those involved in producing a material for sale

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that has some toxic properties.

The final set of disposition choices are deep-well disposal, or destruction by some means such as incineration. These latter methods do not recover costs, and in fact have their own costs. Before considering destruction approaches, all byproducts of any of the treatment systems should be examined together to establish the most effective overall scheme.

The unit processes applicable to inplant control have a variety of uses. Certain of them fit into almost any scheme, regardless of whether reuse, sale, or disposal is the final disposition. Therefore, each of the candidate unit processes will be discussed, along with its particular mode of application.

DISTILLATION AND STRIPPING

In these processes, heat is applied to the waste in a column specially designed to induce separation of the volatile components. The heat is usually in the form of steam. Volatile materials are carried upward and out of column, leaving higher-boiling-point materials behind. When the organics to be removed are at a low enough boiling point so that water is left behind in the tower, these processes can apply.

The vapors leaving the tower can be condensed by cooling, or absorbed by an appropriate sorbent. For example, consider steam stripping of ammonia from wastewaters with high concentrations of ammonia. If the stripped material is condensed, aqueous ammonia can be produced; if absorbed with sulfuric acid, ammonium sulfate is produced.

The applicability of distillation can be determined easily in the laboratory by distilling successive small fractions of the wastewater into a condenser and then analyzing residue and overheads for pollutants of concern. If they pass totally into the overheads before a significant quantity of the water does, the unit process will be applicable.

EVAPORATION

Evaporation is not a frequently used process, primarily because of cost. Its usefulness is limited to high-boiling-point organics and certain inorganic materials. Heat is applied to vaporize the water and the low-boiling-point materials, leaving a residue of the high-boiling-point materials. It is applied to inorganics as a desalting process. The residue can be reused, burned, or stabilized and buried. The design of evaporation systems varies widely and usually incorporates multiple stages, all directed toward economizing on energy applied to evaporate the water.

The test for applicability of evaporation is essentially the same as for distillation. Fractions are distilled off, and the residue is periodically checked. If the target material remains in the residue, and the evaporated and condensed water is clean enough to meet objectives, then the process is applicable.

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SOLVENT EXTRACTION

This process is based on the fact that certain organics are more easily dissolved in certain solvents than in water. As the wastewater is contacted with the solvent, the pollutants are selectively removed from the water and dissolved in the solvent. Obviously, the solvent must have a low solubility in water so it can be separated along with its captured pollutants. Usually, the solvent/pollutant mixture then is passed to a distillation column for separation. The solvent is recycled for futher use, and the concentrated pollutant is reused, sold, or destroyed.

One of the most common uses to date for this process is removal and recovery of phenol and/or phenolics from wastewaters prior to biological treatment. While phenol is readily biodegradable, only limited levels and limited variability can be accepted in most biological systems. Solvent extraction can easily remove phenol to below the harmful levels. One disadvantage of this process is that the solvent is introduced into the water and, up to the extent of its solubility in water, becomes a pollutant itself. Care must be taken that the treatment system can remove or degrade the solvent.

ADSORPTION

The most commonly known process for removal of specific pollutants is adsorption, available in two forms - activated carbon and synthetic resins. Organic materials are adsorbed on the media as the wastewater passes through. Final concentrations for adsorbable organics are quite low, but not zero, because an equilibrium condition occurs in the adsorption bed.

Resins are designed for certain specific classes of materials. Activated carbon will remove a wide variety of organics in a waste stream, but a priority of such removal exists. Competition for available adsorption sites is a factor.

Generally, higher-molecular-weight organics are preferentially adsorbed on activated carbon. New or fresh (virgin) carbon contains small pores that adsorb lower-molecular-weight organics. Thermal regeneration of carbon burns out these small pores.

Activated carbon can be regenerated by burning the organics in a furnance, or by stripping them with steam or solvents, or both. Burning (thermal regeneration) destroys the organics, whereas stripping permits recovery of a concentrated regenerant stream. The choice of a throw-away or recovery system is an economic one, with recovery favoring the large carbon usage systems.

It is also readily applicable to inplant control, and there are advantages in using it here rather than later in the system. When the technique is applied directly to a problem waste, the concentration of pollutants is higher, increasing the driving force for adsorption. Pollutants from other processes are not present, and interferences to adsorption of the desired pollutants are reduced. With a much narrower spectrum of pollutants,

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it may be possible to recover and reuse the adsorbed materials by stripping the carbon.

CHEMICAL OXIDATION

Like adsorption, this unit process can be more attractive on a specific waste. When it is applied directly to a problem waste, other nonproblem organics are not present and therefore the cost of inadvertent oxidation is avoided.

CHEMICAL COAGULATION AND PRECIPITATION

This process has broad applicability to removal of heavy metals from wastewater. It is limited in its ability to achieve low levels in the final effluent because of the solubility of metal compounds formed. Other substances in the waste can affect that solubility, and it is seldom possible to achieve theoretical solubility as may be taken from a handbook. Laboratory testing can easily establish chemical dosages and final expected values. By applying coagulation and precipitation directly to the process waste containing the metal, total effluent concentrations may be within control limits.

ION EXCHANGE

Ion exchange uses resins that are specific to certain metals for extracting them from the wastes. It is generally capable of reaching lower final effluent values for metals than can chemical coagulation and precipitation. The resins are regenerated with various salt solutions that drive off a concentrated soluble metal salt. This brine must be disposed of, and chemical coagulation can be used to remove the metal as a solid sludge. Ion exchange can polish a chemical coagulation effluent or be used directly on the waste. The exact configuration is a function of costs and the final effluent value needed.

CONCLUSION

The control of specific pollutants in industrial wastewater for the 1980's will require considerable innovation. The creativity cannot be left just to the wastewater control engineers who are responsible for end-of-pipe treatment. Company research departments, the process decisionmakers and the operating superintendents must all combine their talents to provide processes which minimize or eliminate pollutant generation, and contain the potential for pollution within the process area. As has always been the case, problem definition and understanding the true cost of pollutant generation are basic stepping stones to proper choice of control alternatives. Once such process modification has been installed, operating vigilance over wastewater must parallel the other normal operations objectives.

INNOVATION IN CONTROL OF NONTRADITIONAL INDUSTRIAL POLLUTANTS

James W. Patterson, Ph.D., Professor and Chairman
Pritzker Department of Environmental Engineering
Illinois Institute of Technology

The capabilities demanded of pollution abatement technology today are far different from the needs of even a decade ago. Prior to the 1970's, less than two dozen traditional pollutants such as BOD or suspended solids, and nontraditional pollutants such as cyanide or toxic metals, were regulated. As we enter the 1980's, the list of 129 toxic pollutants alone includes 13 heavy metals, and over 100 toxic organic compounds. This list is only one example of the multitude of environmental pollutants which will require regulation during the twentieth century.

A critical need exists for new and innovative technologies to cope with this expanding array of nontraditional industrial pollutants, and to control these pollutants to the low levels mandated by current legislation and long-term environmental risks.

During the past ten years, a considerable amount of my professional effort has been spent in tracking and evaluating pollution control technologies for industrial constituents such as cyanide, heavy metals, phenolics, oily wastes, and the like. These efforts have included the preparation of two books and numerous reports and articles on industrial pollution abatement technologies. Over this same ten-year period, industry has invested enormous sums of money in pollution control under the impetus of Federal, State, and local legislation. During the past three years alone, industry's investment in water pollution control facilities exceeds $4.7 billion, according to a recent issue of Chemical and Engineering News.

Given these conditions of tightening environmental regulations and major capital investment requirements, one might, in 1970, have anticipated a flood of new and innovative technologies yielding significant performance or economic advantages. My experience, for the two dozen industrial pollutants which I have closely monitored during this time span, is that there have in fact been fewer innovative technologies implemented than I have fingers on one hand, and the picture for near-term innovative technologies still in the developmental stage is equally bleak.

Perhaps my criteria for innovative technologies are too strict, but I think this is not the case. My criteria exclude relatively minor design or operational modifications to existing processes having a long history of previous application, as well as new processes which incorporate serious adverse side effects such as excessive energy consumption or excessive generation of hazardous treatment residues. To achieve innovative status, I suggest that a new technology innovation must incorporate the characteristics of both technological and economic potentials, as well as achieve an added degree of environmental protection.

I do believe that there are a number of areas of opportunity for innovation in the control of industrial wastewater pollutants. Four example areas are described below:

1. Innovative new physical, chemical,or biochemical processes for pollutant reduction, elimination, or recovery.
2. Innovative new hardware, which enhances the application for pollution abatement of known environmental control or other industrial processes.
3. Innovative application of existing industrial processes and/or hardware not currently utilized in pollution control.
4. Innovative operational techniques which enhance the reliability or overall performance of established processes.

I maintain, however, that although a knowledgeable environmental engineer might cite one or two recent technological innovations within each of these example areas there have in fact been very few significant breakthroughs in industrial pollution control technology within the past two decades.

Further, our attention has been almost wholly focused upon end-of-pipe treatment, usually of composited, self-diluting waste streams gathered from across a whole industrial facility. I suggest that the most fruitful opportunities for innovation, particularly with regard to nontraditional pollutants, lie not at the end-of-pipe, but within the manufacturing facility itself, at the point of pollutant generation and where it is in its most concentrated form and isolated circumstance. If we blend this isolated process stream with others of dissimilar nature for end-of-pipe treatment, the opportunity for innovative control is lost and replaced by the necessity for brute, non-selective control procedures.

It is within the plant that manufacturing process modifications, such as raw feed stock prepurification, or changes in reactor conditions must take place. It is within the plant that innovative clean manufacturing processes must be introduced, to reduce or eliminate the occurrence of unwanted side reactants or loss of valuable raw materials or product. And it is within the manufacturing plant, at the point of waste generation, that the opportunity for pollutant capture is greatest and where we must initiate our programs in recovery, recycle, and reuse. I do not exclude the opportunities for innovation in end-of-pipe technology, but I do believe that opportunities for in-plant innovation for industrial pollution abatement at least match, and perhaps exceed those associated with end-of-pipe treatment.

Let me mention some example opportunities which I believe exist within the plant for pollution abatement. Within an industrial context, a pollutant might fall into one of three categories:

1. The pollutant originates as a raw material impurity, or is a product of reaction of that impurity to yield a secondary undesirable constitute. In this instance, a logical strategy of control might involve prepurification of that raw material to prevent the entry of that impurity into the reactor.

2. The pollutant may result as either a side reactant, or an intermediate product of the manufacturing process. That is, the pollutant is neither a raw material nor a desired product, but represents a loss of product yield through side or incomplete reaction. Two alternative innovative opportunities which might be available are (a) reactor process modification to enhance the desired product yield and thereby reduce or eliminate the undesired side reactants or intermediates, or (b) the substitution of innovative and new "clean" reaction processes which avoid or reduce the generation of side reaction products or the incomplete conversion of raw material to product.

3. The third category represents the instance when the pollutant actually represents the loss of a valuable raw material or product from the manufacturing step. Here the opportunities for recovery, recycle and reuse are maximum, since the industry gains both by recovery of a valuable material, and avoidance of the cost of treatment of that material as a pollutant.

Such opportunities for pollutant avoidance, elimination, reduction, or recovery might not exist for every pollutant or industrial process. However, even when objectives such as these cannot be achieved, I suggest that capture and treatment of the pollutant at the immediate source point can provide significant benefits for innovative control, through the application of highly specific destruction techniques appropriate for the concentrated and isolated process waste stream.

Chairman McDermott: I would like to give the audience the opportunity to express their views or ask the panel questions.

Question (Francis Mayo, Director of the Municipal Environmental Research Laboratory for EPA, Cincinnati): Neither of the panels has painted a very optimistic picture about the pace at which we might anticipate innovative technologies to come forth to meet environmental pollution control needs.

In an effort to try to address the issue, the Congress is making the innovative technology amendments to the Water Pollution Control legislation. This provides that the Federal Government accepts an element of risk in the fostering of the application of innovative technology to the extent of assuming 100 percent of the cost of replacement of those innovative technology installations that are either excessive in the cost of maintenance and operation, or just do not work effectively.

I would appreciate if members of both panels could comment on the appropriateness of the Federal Government accepting that kind of risk; and if you do think it is appropriate, how widely might it be applied as a mechanism for fostering the application of innovative technology?

Response (Robert E. Pailthorp): The Government agreeing to replace innovation technology if it doesn't work is almost essential to any city council undertaking the projects. They really didn't have nearly enough incentive to be willing to take the risk.

Another aspect of innovation is that our firm, and I am sure other firms also, don't think of innovations as breakthroughs. Most consultants -- and I recognize that consulting is really a broad term -- are not involved in fundamental research to develop truly new concepts. There is no mechanism that my firm would have, for instance, to develop a 5,000-foot deep well into which to put a reactor. I think we really have to count on the universities, the Government, and Manufacturers to spend the money to develop the breakthroughs.

Response (James W. Patterson): I think everyone on the panel and the bulk of the audience would agree that real innovation probably comes out of fundamental and basic research, and the fact of the matter is that in the wastewater field we have depleted any pool of basic research findings that we had developed over the last fifty years. There has been very little basic research, either centralized or dispersed, throughout the country on basic phenomena associated with pollutants.

We may be facing a bankruptcy in our basic research pool at this point. Clearly, the new centers that the EPA is establishing now are intended to provide a focal point for such research, but they are only just getting underway. It is going to take quite a time before productive basic lines of research can be set up.

Question (David Stephan, Environmental Protection Agency, Cincinnati): I was curious that none of the individuals in the panel mentioned what to me is potentially a very promising innovation in biological waste treatment. And that is the use of "super bugs" -- genetically engineered organisms to do things a bit differently.

Response (W. Wesley Eckenfelder, Jr.): Dave, my experience at this point with the super bugs, to use that term, has been that they have been very successful in correcting a problem, but I have not seen any application where they have been economically viable on a continuing application basis. There may be some but I haven't found them yet.

Question (Nick Zaleiko, ENERCOL Corporation): Being in the manufacturing field, like the gentleman before, I am very sorry not to see representation from the manufacturing industry on the panel.

The second thing I'm really sad to hear about is the alleged lack of innovation in the water field. I don't think this is true. There are many, many opportunities. We are in the process of completing a seven-year literature research program of various types of technologies all over the world, and there exist techniques different from what we have been using as a "security blanket," namely a "sludge blanket," as the only waste treatment -- the pretreatment of highly concentrated substances or for weaker materials.

One of the more recent breakthroughs in innovative technology, for example, is the utilization of catalyzed and uncatalyzed ultraviolet disinfection. The people who were in this field were far from encouraged by anyone in the organization.

Session II
Technology Assessments

Presiding Chairman:
Robert R. Perry
Assistant Executive Director
Water Pollution Control Federation

Municipal Wastewater Pollution Control Technology

Chairman:
William J. Katz, Ph.D.
Director, Technical Services
Milwaukee Metropolitan Sewerage District

Panelists:
Paul R. Erickson
John J. Convery
Robert M. Gruninger
Denny S. Parker

INNOVATION IN MUNICIPAL WASTEWATER TREATMENT

William J. Katz, Director, Technical Services
Dannette H. Lank, Technical Assistant
Milwaukee Metropolitan Sewerage District

In the best of all possible worlds, wastewater treatment technology would be in the position of aerospace technology a couple of decades ago. There would be a clear, almost universal commitment to a common goal (i.e., getting to the moon) and the resources to single mindedly pursue that goal. At conferences such as this we would outline our need for innovation and basic research to industry and university researchers. The needed innovations would then be supported by Federal funding and, more importantly, by the prospect of a strong market for newly developed technologies.

The Clean Water Act was enacted during a groundswell of environmental consciousness which, in a sense, rivaled the public commitment to the space program. The goal of eliminating pollution discharges and the basic mechanism for achieving that goal were established when clean-up-at-any-cost was a popular concept.

Any close comparison between the space program and the nation's effort to abate water pollution ended shortly after the Clean Water Act was established. The necessary long-term education of the public and local officials failed to emerge. A void developed in translating water quality ideals into widespread understanding of the realities and possible solutions to water quality and solids disposal problems. Clean water is noble -- sewage treatment is not. Billions in Federal aid for construction grants is grand -- the regulations and strings attached to grants funding are bewildering.

Authorizations of $43.5 billion in Construction Grant funds sounded enormous in 1972; now that the costs of large urban projects are known, the amount seems wholly inadequate. And actual appropriations have fallen over $13 billion short of this authorized level!

More importantly, unlike the effort to send a few people to the moon, the funds and the construction required to clean up the water affects citizens quite literally where they live.

The massive public works projects mandated by the Clean Water Act inherently involve complex planning, economic and environmental tradeoffs, and political decisionmaking at almost every level of government. In Milwaukee, and elsewhere, citizens are viewing pollution abatement programs and are asking "Is the improvement in water quality worth the cost to us? What benefits will we see? Can you guarantee the system will work? Are the program benefits worth the potential adverse environmental impacts? Will we be able to afford the cost to run the new system? Will it require more trained operators than are available locally?"

Beyond the questions about specific pollution abatement plans is an even broader question: In a time of increased economic instability, where does the goal of Clean Water stand amid the priorities of increasingly burdened taxpayers? An elderly inner city resident in Milwaukee expressed the dilemma rather eloquently at a public hearing on Milwaukee's proposed Water Pollution Abatement Program:

> "Hell," she said, "if the gas bill keeps on running and the electric bill keeps on going we won't need no damn clear water, we'll be dead ... One death is as bad as another. I would just as soon die from impure water as walk around and freeze to death or starve to death."

At the same hearings, representatives of environmental groups were urging us to vastly increase the proposed $1.6 billion dollar program to treat all urban runoff. The days of a unified "environmental movement" and of widely shared environmental goals are long past.

Further complicating the public's ambivalence about sewage treatment projects is an uneasiness over the future of regulatory requirements and legislative support for the municipal Construction Grants Program. It is apparent that the commitment to 75% Federal funding of sewage treatment projects will not exist when the large, really expensive projects are ready for construction. Grant fund impoundments and restrictions on eligibility for grant funds reinforce this general uneasiness.

The Federal funding question has a significant impact on innovation in municipal wastewater treatment. Some amount of risk is usually involved in innovation -- whether a new process is involved or a new variation of an old process is being proposed. Frankly, there is little incentive for an engineer or municipality to take risks even under the best of circumstances. Any potential failure becomes a political liability when viewed by an already skeptical, possibly hostile, public.

Innovation in wastewater treatment technology cannot, therefore, be promoted in a vacuum. The technological innovations we seek must respond to needs grounded in political, economic and social reality. The concept of innovation must necessarily be broad. Who is to say, for instance, what is more truly innovative — developing a process to achieve 5/5 effluent standards consistently or developing data and modeling techniques which might show that spending millions to achieve 5/5 standards won't significantly improve the receiving waters?

It is paradoxical that funding and political uncertainties nevertheless provide a prime motivation for developing innovations. The same climate of inflation and scarcity makes it imperative for us to develop new ways to get the biggest environmental return from the limited dollars available.

It goes without saying that new and improved technologies, management systems, and institutional arrangements are needed to solve pressing water pollution problems. The kind of innovation we need relates directly to the uncertainties at hand. We need innovations which provide:

- lower energy consumption
- lower costs -- both capital and O & M
- improved process and equipment reliability
- a reduction in adverse environmental effects, such as odors and toxicity problems.

Some specific examples of needed innovations include cost effective, reliable, and environmentally sound processes/equipment for:

- solids disposal, including improved equipment for incineration, pyrolysis, and co-disposal
- energy recovery
- nutrient recovery
- disinfection
- stormwater treatment.

Design innovations are needed, as well, to provide:

- modular designs to allow for planned growth
- dual-use facilities
- process flexibility to allow for changes in regulations and treatment needs
- the ability to remove and adapt to varying industrial pollutants
- improved process control techniques.

As the planning for large projects progresses, other -- and possibly more significant -- needs for innovation are becoming apparent. We have a critical need for data and techniques to reliably determine the beneficial impact of pollutant removal on receiving waters. As noted earlier, clean-up-at-any-cost is no longer an operative philosophy. Therefore, if we are to do the most good with the available dollars, "innovation" must include answers to basic water quality questions.

Improvement in construction techniques and materials is another area of needed innovation. Milwaukee's clear water problems offer a good example. In our case, the development of new, low-cost techniques for repairing laterals and manholes and for disconnecting foundation drains could provide far-reaching cost savings for property owners and for the Water Pollution Abatement Program. The ability to cost-effectively eliminate greater amounts of inflow and infiltration could provide a significant reduction in costs for conveyance and treatment.

Management innovations can likewise offer significant cost savings. In Milwaukee, the use of Progam Management has allowed us to produce a facilities plan in two years, as opposed to the average time of three years. In a $1.6 billion project, the elimination of a year's inflation is a major cost savings. This and other types of management innovations can have a payback equal to or greater than more "traditional" technological innovations.

It is encouraging that EPA has recognized the need for innovation and has developed an Innovative and Alternative Technology program to promote and reward innovation. It is essential, however, that explicit, quantifiable goals be established for this program and that these goals relate directly to optimizing the return on Construction Grants funding. The program should require and support all justifiable means of lowering project costs while achieving desirable environmental benefits. At the same time, it is important that this program not develop into yet another set of mandatory, project-slowing requirements.

It is a challenge to all of us to innovate wherever possible and to encourage innovation in the projects we manage. Left to our own devices, innovation would occur as a natural byproduct of attempts to save money, make money, and/or provide better solutions to water pollution problems. The funding and regulatory environment, however, throws up some substantial barriers to the risk-taking required for innovation.

Stability, both in Construction Grants funding and in grant regulations, is critical to any long-term encouragement of innovations. We have to know that funding will exist and that the rules of the game won't change in mid-project.

We also need more risk-taking on the part of EPA and the State regulatory agencies. Innovation is frequently thwarted by the narrowness of existing regulations and the need to provide neat packages that fit nicely into the existing review process. The regulatory personnel reviewing projects must take risks. Perspective must be applied to the review process, recognizing the cost associated with a day's delay. A one-day delay in Milwaukee's Water Pollution Abatement Program (calculated on the basis of 8% yearly inflation for a $1.6 billion project) costs taxpayers in excess of $300,000. The Construction Grants process, as a whole, needs to be analyzed to determine where requirements can be cut, where more discretion can be afforded to the Regional Administrator, how cost-effectiveness regulations can better promote innovation, and how project funding and construction can be speeded up.

Experience has shown us that there are risks for everyone involved in municipal wastewater treatment. Given a choice, however, the risks of not innovating are, in the long run, infinitely more ominous.

INNOVATION IN THE ENVIRONMENTAL TECHNOLOGY INDUSTRY

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INTRODUCTION

To understand the "Rexnord" perspective on innovation in industry I would like to briefly explain our R&D Scenario. We follow the centralized/decentralized R&D approach where approximately 50% of the annual strategic resources are directed to divisions - mining, material handling - power transmission (mechanical and hydraulic) - environmental, construction machinery, process control instrumentation, etc., and the other 50% to Corporate R&D where four Directors identify longer term projects in concert with corporate objectives - typically higher risk or longer payout. Further, we will organize technical teams linking expertise in the four Director areas to capture the maximum interdisciplinary skills required on a major project. In some cases R&D activity will spawn a venture and ultimately an independent division within Rexnord.

Some of our divisions are designated as manage -for-cash industries where the emphasis is on production efficiency. Other industries are designated as invest-and-grow areas where product lines should be added or improved. Over the last ten years Environmental Control process and equipment division (Envirex) serving the municipal and industrial market has been designated as invest-and-grow, but recently due to changing market conditions we have changed that to an "earn-and-protect" category.

Approximately one-third of our Environmental R&D effort is directed toward Envirex, the other two-thirds to Contract Research projects for EPA, Department of Transportation, NIOSH, Office of Water Research, and other Government agencies. Particular emphasis in Contract Research is placed on highway runoff and the fate of pollutants entering into the environment; field scale water reuse in industries such as pulp and paper, chemical, iron and steel, food, and aluminum. Toxic and hazardous waste treatment and control; developing storm water overflow treatment, sludge dewatering, anaerobic digestion; and an air technology group concentrating on minimizing workers' exposure to respirable dusts, trace metals, and welding fumes--these briefly capsulate our ongoing Contract Research efforts.

Internal programs for Envirex are intensive in aeration, sludge dewatering, anaerobic digestion, and polishing of secondary effluents via ultrafine microscreening, (1, 6, and 18 micron). Noteworthy is technical participation in the EPA international program for upgrading final clarifier performance and the separate EPA project using new dye tracer techniques and analysis in full-scale units. Also we continue to participate in the ASCE Committee dedicated to establishing O_2 transfer test standards for the industry. EPA also has a role in this committee.

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An Overview of Environmental R&D in the 1970's

We charged into the 1970's as a nation realizing that there was a tremendous wastewater cleanup job to be done.

Some championed the "physical/chemical syndrome" activated carbon adsorption route, while others claimed pure oxygen as the way as compared to conventional air-activated sludge.

Nutrient removal - tertiary treatment technologies - emerged and we envisioned another sequential generation of treatment plants.

As more plants were upgraded and expanded, sludge disposal became critical and heat treatment and/or incineration was favored over digestion. Storm water overflow also required R&D programs and projects.

Then the energy crunch hit and we began to reevaluate the energy-intensive processes such as aeration and sludge disposal.

As Rexnord (Envirex) has a broad span of product and process interests--screening, primary and final clarification, multiple aeration products, sludge digestion and sludge dewatering--a wide range of R&D projects were required to maintain and improve product acceptance and use.

In retrospect, all of the shifting of the technologies to and away from activated carbon, the impact of pure oxygen plants, the swing from anaerobic digestion and back, has induced certain technology cycles into R&D. Perhaps like Moses we have been in the wilderness but only ten years and now a turn to the right will get us into the oil fields. Where certain products had matured it was necessary to champion renaissance R&D projects while critically selecting new product and process technologies. Obviously constant justification and accountability is necessary to stockholders of a publicly owned corporation such as Rexnord.

The highly variable annual rate of EPA Construction Grant funding authorization has resulted in some commercially favorable and unfavorable years - as the commercial year goes so goes the R&D year in terms of what funds are available for product and process development. Understandably, R&D has had some "Roller Coaster" rides in the 1970's, shifting emphasis on programs.

The strategy of the late 1970's to require use of the lowest bid equipment encouraged a number of "late entries" into the industry. This has spawned a series of "me-too" products at the expense of R&D investment in the private sector or at least reduced to low priority the investment of funds to improve process or product quality.

Please let me emphasize that Rexnord advocates the competitive process, which is the cornerstone of the Free Enterprise System. Now let me define the competitive process as it relates to the municipal treatment field.

Example:

As we look at the head end of a plant the need for brute force mechanical bar screen and grit collection equipment is absolute. It is the "swords point" by the treatment process. A need for basic hydraulics design is understood. Any attempt to subtly lighten up the design fabrication or fit up of this equipment has dramatic impact in operating and maintenance and potential for bypass of untreated storm flows and/or lift station surges.

As we progress downstream, mechanical design is still important but process technologies in clarification and thickening, process rate transfer expertise for O_2, biological kinetics, and chemical treatment, digestion, and heat transfer all demand a synergy of technical disciplines.

We believe that the municipal treatment products need these types of continued technology backup within this industry. It is necessary to properly represent the product to the consultant specifying and designing the uses for proper startup, long-term operation, and maintenance.

We invite the competitive process where this technology base underwrites the product and process available from private industry. We believe that the consultant contractor and municipal sector also endorse this position for cost-effective implementation.

Finally like Marco Polo, we (the industry) have voyaged to the East in search of product and process license opportunities. We imported aeration and sludge handling technologies. After a generation or two of Americanization in their use, the concepts of the licensed process or product became acceptable only after proof testing, adaptation, and redesign.

If this carries the banner of the "Not Invented Here Syndrome" so be it. Rexnord has licensed products from overseas, however; as a general rule the product has not been ready for immediate full-scale use. R&D programs are still needed to transform the product into an acceptable product for use in American plants. Our programs are designed to minimize any designer or user receiving the "Guinea Pig" treatment. This strategy is in obvious conflict with the "late comer" and "me-too" approach associated with the mandatory low bid policy of the late 1970's.

These factors, "trial and error technology", highly variable annual funding rates and the lowest cost equipment syndrome took us through the 1970's. We should recognize their impact on R&D and now establish and organize our current and future priorities.

Current Environmental R&D

Presently we at Rexnord/Envirex have intensified our efforts in internal programs to further develop:

a. least energy intensive aeration processes, realizing that oxygen transfer, mixing intensity and basin geometry are all key factors

b. anaerobic digestion and gas utilization

c. the sludge dewatering processes as the belt press and filter press options are more widely used

d. final clarifier performance analysis

e. instrument product and microprocessor base control

f. the use of plastics - inhouse formulation and production of nonmetallic components to lengthen equipment life

g. ultra fine screening of final plant effluent

h. hydraulic fluid power drives where they are cost-effective over conventional gear reducers and chain drives.

In addition we have been attracted to the DOE scenarios where a significant portion of sewage treatment technologies are applied or are the starting data base.

This is particularly true of anaerobic digestion applied to renewable energy-derived organic feed stocks.

As the DOE programs spawn new technologies, I am certain there will be impact on the municipal treatment field.

Obvious examples are:

a. Low-cost solar collectors (solar collectors are marginally or less than cost-effective now). In five years the volume of solar collectors and material development will become more favorable.

b. Chemical conversion of cellulose to simple sugars in the emerging biomass field will impact on pretreatment of digester sludge. We must move from the 50% organic conversion to methane up to 70%, hopefully 90% and hope this will significantly reduce the volumes of sludge hauled away but more critical, extract more methane for energy.

Now we are ready to look into the 1980's.

First let us not forget the municipal plant operator and staff. How do we relate to the sector that runs the plant 24 hours/day? Where are the weak links in process or maintenance that need shoring up? How do we prepare operations for the microprocessor age and for what size plants is this cost-effective?

How can instrument detection--online monitoring, recording and control--result in faster response to a changing condition?

Many predict the 1980's and certainly the 1990's will produce a water shortage crisis that will make the petroleum shortage of the 1970's appear to be a minor incident. In the Midwest and portions of the Northeast we have been somewhat oblivious to this mounting water crisis with our higher water tables and Great Lakes supplies. As a nation, our dependable supply of water is 600 billion gallons or 3% of the world's supply. In 1960 we used 200 BGD; in 1970, 370 BGD; and by 1985,420 BGD without any major energy push for oil shale, coal gasification, etc. Currently we use 9% of our water domestically, with 43% going to industry and 4% to agriculture. Thus the 9% plus a portion of industry's use is what our publicly owned treatment works (POTWS) are concerned with.

The point of all this is that water reuse from municipal treatment plants is the major challenge in the 1980's. What technologies are required to permit municipal effluents to be used to recharge falling ground water levels? This is already critical in Arizona, California, West Texas, Nebraska, and Wyoming. These areas are all in the "mining" for water mode where water tables have dropped as much as 400-450 feet in the last ten years.

Is municipal effluent a resource to be used as an "offset" to permit a go-ahead in mining Western coals, pushing coal slurry pipeline transport ahead, or impacting on oil extraction from shale?

Finally an innovative and alternative technology program is two years old -- heavy on alternative and light on innovative. What is wrong and how do we gear up the innovative sector?

First, the innovative or alternative technology starts in the Step One grant process. I believe this is too late for an innovation to get into the grant cycle.

A funding program should be set up to cover pilot or retrofit on a one-basin or test program basis. Then results could move into Step One and be scaled up on a rational design basis.

As a minimum, a municipality, consultant or manufacturer, or combination of these sectors would offer bench scale results as "proof concept" ready for pilot or tank conversion testing. Seldom can an innovative idea or bench test leap to full-scale design without extreme risk or expensive full-scale modification.

To Summarize

The 1970's have established a direction for us and established:

1. An optimized air activated sludge process is cost-effective.

2. Nutrient, especially nitrogen, removal will be important as we move into reuse, especially ground water recharge.

3. The products and processes offered by this industry must be backed up with a solid technology base. Municipalities, consultants, contractors and, we hope, EPA expect this.

4. The EPA demand for "lowest equipment price" has opened a "Pandora's box" of premature equipment failure and turned private industry to other sectors for R&D efforts.

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INNOVATIVE MUNICIPAL TECHNOLOGY

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INTRODUCTION

The Innovative and Alternative (I/A) Program which began October 1, 1978, was only authorized for an initial three-year period and is due to expire September 30, 1981. Should EPA recommend reauthorization of this program? If the answer to that question is yes, then what changes, if any, should be recommended? These decisions are only part of the Agency's extensive efforts to reevaluate the whole Construction Grants Program through development of a 1990's strategy. The strategy, which is due to be completed by the end of the year, will include legislative initiatives, management reforms, and administrative changes. Preliminary concept papers, including one on the I/A Program (1), have been produced as part of the 1990's strategy development process. An EPA contact, for the purposes of requesting copies of the concept papers or for providing your comments on the issues, is identified in the reference section of this paper. The issues identified in the I/A Program concept paper are shown in Table 1.

Table 1. I/A Program issues.

- Conservatism in the water pollution control industry
- Short-term experimental nature of the program
- Inequities in demand and distribution of State I/A set-aside funds
- Administrative and technical complexity of I/A program
- Insufficient Federal grant incentives to municipalities
- Quantity, not quality, orientation of I/A program
- Lag time between funding allocation and program implementation step 2 and step 3.

The purposes of this paper are to present a brief summary of the I/A Program to date, identify technologies that have been considered "innovative," and stimulate constructive thinking on how the program can be improved.

I/A PROGRAM

The Congress of the United States in passing the Clean Water Act Amendments of 1977 [PL 95-217, Sections 201(g), (i), (j), 202(a), 205(i)] provided the legislative justification for the I/A Program. The Act provides several major economic incentives. These are shown in Table 2.

Table 2. Major economic incentives of the I/A program.

- An increase in Federal grant share from 75 percent to 85 percent for I/A projects
- A 15 percent cost-effectiveness preference for I/A technologies
- A 100 percent warranty of replacement or modification costs should the I/A technology not perform satisfactorily
- A 2 percent bonus design fee for the consulting engineers of I/A technologies
- Set-asides in the State construction grant allotment (3 percent in FY80 and 81). An inclusive set-aside of 0.5 percent specifically for innovative technologies.

Technologies are defined in the implementing regulations (2) and the I/A Assessment Manual (3) as conventional, alternative or innovative. Conventional concepts of treatment are defined as biological or physical-chemical processes conventionally used for the treatment of wastewater and which result in a point discharge to surface waters. Alternative technologies are specifically defined technologies which generally provide for reuse and/or recycle of resources. Alternative technologies are listed in Table 3.

Table 3. Alternative technologies.

Effluent Treatment

land treatment

aquifer recharge

aquaculture

silviculture

direct nonpotable reuse

horticulture

revegetation of disturbed lands

containment ponds

treatment and storage prior to land treatment

preapplication treatment

Sludge

land application

composting prior to land application

drying prior to land application

Energy Recovery

co-disposal of sludge and refuse

self-sustaining incineration

anaerobic digestion with > 90 percent methane recovery

Individual and On-Site Systems

- on-site treatment
- septage treatment
- alternative collection systems for small communities

Conventional concepts of treatment can become innovative if they are capable of achieving either a 20 percent net primary energy reduction or a 15 percent life cycle cost reduction. Alternative technologies may be classified as innovative if they meet either the cost or energy criteria or any of the four improved application criteria: (a) improved operational reliability, (b) improved toxics management, (c) improved environmental benefit, and (d) improved joint treatment potential. Characteristic of and necessary for a determination of innovation is advancement of the state-of-the-art and the assumption of increased risk commensurate with the benefit to be achieved. The cost and energy reduction requirements are the only quantitative criteria. The other criteria are more judgmental with decisionmaking authority delegated to the Regional Administrators.

ACCOMPLISHMENTS OF THE I/A PROGRAM

EPA has established a Technical Support Group within the Wastewater Research Division of the Municipal Environmental Research Laboratory in Cincinnati to assist the Office of Water Program Operations in Washington, D.C. and the Regions in implementing the I/A Program. The Technical Support Group reviews the I/A facility plans, maintains an I/A clearinghouse and provides, along with staff of the Robert S. Kerr Environmental Research Laboratory in Ada, technical and administrative assistance to municipalities, consultants and State staff in developing I/A projects as a part of the Agency's Active I/A Program initiated by EPA Administrator Costle in March 1980.

Other initiatives of EPA which may be significant from a marketing standpoint include: (1) encouragement of sole source procurement for innovative technologies, and (2) promulgation of an interim policy on exemption from traditional patent regulations for innovative technologies.

EPA is also cooperating with the Water and Wastewater Equipment Manufacturers' Association (WWEMA) in conducting a series of seminars on new developments in wastewater treatment technology. A schedule of the remaining seminars is shown in Table 4.

Table 4. New Technology Seminar Schedule.

Location	Date
Dallas, TX	Nov. 12-13, 1980
Kansas City, MO	Nov. 17-18, 1980
Denver, CO	Nov. 20-21, 1980
San Francisco, CA	Dec. 10-11, 1980
Seattle, WA	Dec. 17-18, 1980
Boston, MA	Jan. 13-14, 1981

The latest quarterly report (4) provides a perspective on the progress of the I/A Program. As of June 30, 1980, EPA has approved 248 I/A technology projects, accounting for $27.2M (32 percent) of the FY79 set-aside funds. The number and types of alternative technologies approved to date are shown in Table 5.

Table 5. Funded alternative technologies.

Effluent Treatment

land treatment - 69

aquifer recharge -10

direct nonpotable reuse - 7

containment ponds -44

treatment and storage prior to land treatment - 74

preapplication treatment - 5

Sludge

land application - 28

compost prior to land application - 8

drying prior to land application - 3

Energy Recovery

co-disposal of sludge and refuse - 2

self-sustaining incineration - 1

anaerobic digestion with >90 percent methane recovery - 17

Individual and On-Site Systems

on-site treatment - 16

septage treatment - 6

alternative collection systems for small communities - 25

The total number of alternative technologies (315) exceeds the number of alternative projects (224) because some projects incorporated more than one alternative technology. These alternative projects obligated $23.1M or 37 percent of the alternative set-aside of $63M.

INNOVATIVE TECHNOLOGIES

Of the 31 innovative projects funded, 7 meet the 15 percent life cycle cost reduction, 8 meet the 20 percent net primary reduction, 10 had increased environmental benefits and 11 were approved through regional discretion. The number and type of innovative projects funded through June 30, 1980 is shown in Table 6.

Table 6. Innovative projects funded as of June 30, 1980.*

Oxygen Fluidized Bed - 1

Integral Clarifier Aerator - 1

Ultraviolet Light Disinfection - 6

Waste Pickle Liquor Use - 1

Deep Turbine Aerated Oxidation Ditch - 1

Hydrograph Controlled Release Lagoon - 1

Solar Heating of Digesters, Buildings or Water - 3

Powdered Activated Carbon Treatment and Regeneration - 1

Mixed Facultative/Aerated Lagoon/Stabilization Pond - 1

Overland Flow - 5

Storage Pond - 1

Unique Design Spray Irrigation - 1

Intermittent Sand Filter - 1

Recirculating Rock Filter - 1

Upflow Packed Tower Nitrification - 1

New Lagoon Treatment/Storage/Irrigation -1

Energy Recovery From Effluent Using Heat Pumps -1

Pretreatment Storage and Wetland Discharge - 1

Facultative Sludge Basin and Dedicated Land Disposal - 1

Microscreening Lagoon - 1

*Some of the above projects were funded without I/A TSG review and recommendations.

These projects represent a total obligation of \$4.1M which is 20 percent of the FY79 innovative set-aside of \$21M.

The pace at which I/A projects are submitted, reviewed and approved accelerated through the July-September 1980 period which was to have been the final quarter for obligating the FY79 set-aside funds. Recent legislation reauthorized the use of FY79 set-aside funds for another year. A complete analysis of the I/A program activity through September will be included in the next quarterly report which will be completed at the end of October. Program projections anticipate that 80 percent of the FY79 I/A set-aside funds will be obligated by September 30, 1980.

Since June 30, 1980 a number of additional technologies have been proposed and recommended for innovative funding. Some of the more interesting projects, not mentioned previously, are included in Table 7.

Table 7. Selected innovative projects reviewed since June 30, 1980.

- Gas production at municipal sludge/industrial feedlot disposal facility
- Dual aerobic/anaerobic sludge digestion
- Vacuum filter/belt filter press series dewatering
- Gravel bed treatment of community septic tank-sand filtered effluent
- Intermittent sand filters with floating hydraulic dredge
- Tubular screw pump for raw wastewater

- Paygro mechanical composting
- Sludge-stabilization facultative lagoon/stormwater retention treatment basin
- Extended lagoon holding to meet a disinfection criterion
- Phostrip process.

In addition to the I/A Program support activities, the Division funds the development of potential innovative processes through its research programs. Potentially innovative processes which are being actively supported by the research program are shown in Table 8.

Table 8. Potentially innovative processes.

Reactor/clarifier
Fluidized bed
Fine bubble aeration
Aerated filter
Activated biofilter
Sequencing batch reactor
Deep shaft aeration
Vertical tube reactor
Anaerobic treatment

These technologies frequently have comparable approaches in design or performance objectives to achieve the cost and energy savings characteristic of innovative technologies such as:

1. improved space utilization by performing multiple process functions in the same space as well as achieving higher unit loadings
2. improved oxygen transfer and utilization thereby reducing and, in one case, even eliminating aeration requirements and associated energy requirements
3. improved solids separation through the addition of flocculating zones in clarifiers, solids contact, or fluidized bed modes of operation
4. improved disinfection/stabilization.

Most of the technologies currently funded by the Division are oriented toward the secondary biological treatment and sludge treatment and disposal markets which are the best defined. The markets for advanced secondary, advanced waste treatment, storm and combined sewer, toxics management, or other water-quality-based treatment requirements are less well defined at this time. The Agency's current efforts at developing a 1990 Construction Grant Strategy will determine the relative funding priorities of these technology markets. Well-defined markets and stable funding levels will go a long way toward encouraging the private sector to invest in the development of innovative solutions to societal problems like water pollution. The final ingredient which has to be present is the opportunity to earn a decent return on investments. Table 9 illustrates the public and private discounted cash flow rates of return for 20 innovations. This information is reproduced with permission from an article entitled "Measuring the Societal Benefits of Innovation", by J. G. Tewksbury, et al, which appeared in the August issue of Science.

Table 9. Discounted cash flow rates of return on innovations.

Innovation	Rate of Return (%) Social	Rate of Return (%) Private
	Industrial Products	
A	62	31
B	Negative	Negative
C	116	55
D	23	0
E	37	9
F	161	40
G	123	24
H	104	Negative
I	113	12
J	95	40
K	472	127
L	Negative	13
	Consumer Products	
M	28	23
N	62	41
O	178	148
P	144	29
	Industrial Processes	
R	103	55
S	29	25
T	198	69
U	20	20
Median	99	27

Reproduced with permission from an article by J. G. Tewksbury, et al, "Measuring the Societal Benefits of Innovation", Science, August 1980.

The results presented indicate that the median discounted cash flow rate of return on 20 innovations was 99 percent based upon social benefits and 27 percent based upon private benefits. A major finding of the study is that "a number of innovations with substantial social rates of return had unacceptable private rates of return". We in Government need to be keenly sensitive to the economic viability of the industry our actions affect. Discounting earnings for any significant portion of the 7 to 9 years which the average project in our industry takes to complete can make even large future earning projections appear marginal on a current basis. The I/A Program is attempting to shorten the time of completion of I/A projects through higher placement on State priority lists, direct technical assistance, expedited reviews, and special procurement considerations.

REFERENCES

1. Innovative and Alternative (I/A) Technology Program: Interim Concept Paper; EPA interim publication.
2. Federal Register, Vol 43, No. 188; Sept. 27, 1978.
3. Innovative and Alternative Technology Assessment Manual. U.S. EPA. MCD-53; Feb. 1980.
4. Quarterly Report: I/A Program through June 30, 1980. J. Smith to H. Cahill; EPA Internal Memorandum.
5. Copies of this publication can be obtained from: Barry H. Jordan, U.S. Environmental Protection Agency, Facilities Requirements Division (WH-595), 401 M Street,SW, Washington, D.C. 20460.

TRENDS IN SLUDGE MANAGEMENT

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There is nothing new under the sun. (Ecclesiastes 1:9)

This ancient wise statement of Solomon is as true today as it was in biblical times. The sludge management technology now in use has been used in past decades, some in wastewater treatment, some unwittingly and some in unrelated industries. Some of the techniques are widely used while others are underutilized. Emerging techniques are not really new, they have been used elsewhere, or are combinations of various previously used techniques.

CURRENT TECHNOLOGY

Current technology in sludge management utilizes one or more of the following processes:

- Thickening
- Stabilization
- Dewatering
- Disposal

Different techniques may be used to accomplish these processes. For example, thickening may be accomplished by gravity, dissolved air flotation, or chemical means. Dewatering may involve vacuum or pressure filtration or sand bed drying. Stabilization encompasses a wide variety of techniques including heat or chemical treatment, aerobic and anaerobic digestion, composting and others.

One or more of the ultimate sinks may be used for waste disposal - land, air or water. When land is used for ultimate disposal, water resources also may be involved through runoff or via leachate entering the groundwater. Air, land and possibly water sinks may be involved in incineration processes. A major disposal option for sea coast cities has been ocean disposal. Congress has decided this low-cost method of disposal produces unacceptable environmental degradation and is no longer legally permitted. Table 1 shows some of the various techniques that may be used to accomplish the four basic processes.

SHORT-TERM OUTLOOK

Continued widespread use of time-proven techniques for sludge management will prevail for the near term of 3 to 5 years. Thickening coupled with stabilization and dewatering techniques will be utilized. The search for energy efficient methods of sludge processing will be accelerated.

Stabilization techniques that are expected to increase in use during this period are lime conditioning, composting and land application. Concern for the impacts of land disposal techniques on groundwater resources is increasing. The lessons learned from past environmental abuses and insults which caused fouling of the Nation's water and air resources have made us increasingly aware of the need to protect the precious groundwater resource. We can ill afford any more Love Canal incidents.

TABLE 1

REPRESENTATIVE SLUDGE PROCESSING TECHNIQUES

THICKENING

- Gravity Thickening
- Dissolved Air Flotation Thickening
- Chemical Conditioning

DEWATERING

- Vacuum Filtration
- Pressure Filtration
  - High Pressure
  - Low Pressure
- Belt Press Filtration
- Centrifugation
- Sand Bed Drying

STABILIZATION

- Digestion
  - Aerobic
  - Anaerobic
- Heat Treatment
- Chemical Treatment (lime)
- Composting
- Incineration
  - Multiple Hearth
  - Fluidized Bed
  - Energy Recovery

DISPOSAL

- Land Spreading
  - Liquid
  - Dry
  - Raw
  - Stabilized
- Ocean Disposal
- Ash Lagooning
- Atmospheric Emissions

Intensive use of the earth's surface by mankind has reduced the humus values of much of its soil. Additions of controlled amounts of sludge and/or composted sludge can contribute to improving the values of these soils. Moderate sized composting operations can be implemented in relatively short time intervals and at relatively low investments of capital cost. Therefore, composting may be the method of choice for those areas where compost can be profitably used.

Planning in the short term will likely emphasize energy efficient techniques for sludge stabilization and recovery of energy and humus values. It is expected that newly emerging technologies for sludge processing will be developed further. Some of these techniques are adaptations of other industrial practices while others are combinations of currently known and used techniques in the sludge management field. For example, the adaptation of liquid ion exchange technology from the metals processing industry by a Michigan State University team may permit recovery of various elements from metal-rich industrial sludges. The potential of combining aerobic and anaerobic digestion processes to reduce total digestion time and improve energy efficiency is under study in nearby Hagerstown, Maryland. The impacts of these innovations will be evaluated in pilot testing during the next five years.

FORM FOR EPA CONFERENCE MANUSCRIPTS

Please read all attached instructions before you begin typing

Innovative uses of chemical and biological processes for sludge stabilization such as vermicomposting using earth worms and hyperbaric oxyozosynthesis using high purity oxygen and ozone under pressurized conditions are currently under development. Pilot scale feasibility studies have shown some promise for these and other untried processes. In the near term, scale up to partial plant scale or full plant scale testing will be required to establish the long-term feasibility, design parameters and cost data for these processes.

LONGER-TERM OUTLOOK

Looking forward to the 5 to 10 year horizon, our nation faces critical choices regarding energy efficiency. These choices will impact sludge disposal options. The energy efficient processes will survive, those that are energy intensive will decline, and those that provide for the recovery of energy values will be accelerated in development and application.

Incineration, long a suppressed and underutilized technology because of its cost and air pollution aspects may be coupled with heat and/or energy recovery. An additional blend of combustion techniques could join refuse and sludge combustion in a co-firing mode with energy recovery. The demand for the energy values inherent in municipal sludge and refuse is likely to cause a resurgence in this blend of technologies.

Consider an area like the Washington, D.C., Metropolitan Area with its vast quantities of sewage sludge and refuse. Some of the dewatered sludge in this area is transported as much as 50 miles before being buried in the land in suburban areas. Large quantities of chemicals are used to stabilize the sludge in preparation for burial. Then energy is expended to dewater the sludge and transport it to the land disposal site. When one considers the operational costs of such a system, it seems that a hard look at environmental, energy and economic trade-off values is warranted.

Co-incineration of sewage sludge with solid waste is being looked upon as an answer to the sludge disposal problem in several municipalities. The Linden-Roselle Sewerage Authority in New Jersey has pilot tested a system which co-incinerates dried sludge with refuse. The system includes belt filter presses and a steam activated dryer to dewater the sludge, modular combustion units to burn the refuse and sludge, and an energy recovery boiler to produce steam. The city of Harrisburg, Pennsylvania has implemented an energy recovery system to provide a solution to that city's solid waste and sludge disposal problems. At Harrisburg, an existing refuse incinerator and a new sludge dewatering facility have been coupled with a resource and energy recovery system. Sludge from the city's 30 mgd activated sludge and phosphorus precipitation treatment plant will be vacuum filtered, dried in steam heated sludge dryers and pneumatically transfered to the nearby refuse incinerator. The 720-ton-per-day incinerator plant was constructed in 1973 and fires refuse on reciprocating grate stokers. The 35 tons of sludge produced daily is mixed with the refuse and fired in the incinerator. A multi-pass waterwall design boiler produces steam for a number of inplant purposes and excess steam is sold to the district heating plant of the Pennsylvania Power and Light Company. Air quality is maintained by the use of electrostatic precipitators.

In Toronto, Ontario, two wastewater treatment plants are installing thermal conditioning, incineration and energy recovery facilities. Steam produced in the sludge incinerators will be used in the thermal conditioning facilities. Because of thermal conditioning, a high solids sludge cake is produced at the dewatering facility and autogenous combustion is possible. At the 60 mgd Lake View Plant in Toronto, a fluidized bed furnace is used for the combustion process. At the 240 mgd Main Treatment Plant, multi-hearth furnaces are used. In each of the instances cited, currently known but underutilized technologies are being combined in an effort to seek energy efficient and cost-effective sludge disposal systems. In the long term, it is anticipated that innovative combinations of processes will expand our ability to efficiently operate sludge management systems.

Sludge digestion has been an underutilized technique in recent years. Again, cost and energy inputs for heating have been negative contributing factors to the demise of sludge digestion. However, newer techniques such as the Dual Digestion Process being developed by the Union Carbide Company may change the outlook for sludge digestion. This process utilizes high purity oxygen in a first-stage aerobic digester with a hydraulic retention time of one day to increase the biological activity in the sludge and raise the temperature autothermally to approximately 45 to 55°C. No external heat is required according to the Union Carbide literature. After one day, the heated sludge is transferred to an anaerobic digester operating in the thermophilic range where the sludge is retained for an additional eight days. Pilot testing indicates that when operated in the thermophilic temperature range, the process produces a stabilized sludge, reduces volatile solids and pasteurization of the sludge occurs. Daily transfer of sludge from the autothermal aerobic digestion system to the anaerobic system precludes the need for external heating of the anaerobic tank contents. One can readily see the impact of such a system on plants with existing anaerobic digesters where expansion of the plant is contemplated. The residence time in the anaerobic digester is decreased significantly and the capacity of the relatively high-cost sludge digesters is increased with a minimal amount of new construction. As noted, the supplier claims that the process is energy efficient, the end product is stable and pathogen survival is nil when operated in the thermophilic range.

The Dual Digestion Process is being field tested in Hagerstown, Maryland. If the claims for the process can be substantiated, this unique blend of two existing technologies may give us a new dimension in sludge digestion.

Another application of energy efficient technology is the use of solar energy coupled with sludge digestion. The solar heating of anaerobic sludge digesters permits the use of the methane produced in the digestion process for operation of other wastewater plant equipment. A Massachussetts treatment plant has recently installed a solar heating system where this form of energy recovery is playing an important role.

Ultimate disposal of sewage sludges will be concentrated on the land, especially in suburban and fringe communities. The humus values of sludge will be utilized either as direct land application or via the compost route. Continued caution will be observed regarding the types of crops grown on sludge-enriched land. Additional research into the survival of pathogens and the fate of heavy metals and nitrates in the use of sewage sludge on cropland is required. This need is evidenced by the concern of industry for products grown in such soils. The Del Monte Corporation, which is the largest canner of fruits and vegetables in the world, issued a nationwide directive to its crop growers in 1980. Del Monte announced to its growers that it will not accept crops grown on soil to which sludge has been added. Its concern is whether the EPA land-spreading criteria are sufficiently manageable and enforceable. Subsequent to the announcement by Del Monte of its position, the FDA was asked to comment on EPA's land-spreading criteria. Additional qualifiers were developed by FDA which in the future may be adopted as standards for the industry.

CONCLUSION

Future sludge management strategies in urban centers will tend to maximize the use of energy efficient and energy producing techniques. Co-disposal of sludge and solid waste to recover the energy values contained in these waste products is expected to increase. In suburban and fringe areas, land disposal techniques will likely be the choice. Concern for contamination of groundwater resources and for clean air will be prevalent and shape the development of modified technologies. Adaptation of technology from other industries may occur and untried combinations of currently used and underutilized techniques will occur. The dominant factor in future choices is expected to be energy efficiency.

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Question (by unidentified speaker): We have noted on several projects where the consultants have utilized the manufacturer's advertised efficiency. I wonder if the panel might discuss the pro's and con's and psychology of using the process.

Presiding Chairman Perry: You mean the difference between what is advertised and what the reality is in terms of design? Paul, would you like to comment?

Response (Paul R. Erickson): The industry has been plagued with that kind of problem for a number of years and that's why I particularly referred to the committee on oxygen transfer of standards that has been evolving for three years. The standards are just about to be published, and there is a lot of hard work between the consultants, manufacturers, and EPA staff. I would strongly urge that those procedures be followed in specifying the transfer of efficiencies and field testing procedures.

Toxic and Hazardous Waste Incineration Technology

Chairman:
Frank C. Whitmore, Ph.D.
Principal Scientist
Versar, Inc.

Panelist:
Rudy G. Novak
John T. Lurcott
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WASTE CHARACTERIZATION - A DECISION MATRIX

Frank C. Whitmore
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INTRODUCTION

The available options for the disposal of industrial wastes can be summed up as: (a) elimination via process modification, (b) local disposal, (c) cremation, and (d) burial. The first option requires that the manufacturing process be altered in such a way as to eliminate or at least significantly reduce the volume of waste produced. In some cases this may be the most cost-effective option since the values that were originally lost in the waste can often become useful output from the process. Unfortunately, many industrial processes are such that this is not an available option for disposal.

Local treatment has been the most widely used of all disposal options for many years. The waste may be processed by chemical or biological means to a point that the residue may be discharged either to surface waters or to municipal waste disposal plants. Many types of technology are available and are widely practiced by those generators for which these methods are practical.

Many industrial waste streams have characteristics that demand disposal by either incineration or burial. In these cases, the destruction by incineration will usually be more cost-effective over the long run because the responsibility of the generator ends when the material has been destroyed. The critical (and obvious) questions that must be asked are whether the waste is incinerable and if so, under what conditions with what technology? Thus, the decision process faced by the generator must consist of a determination of the incinerability of the waste, a mating of the characteristics of the waste to the appropriate incineration technology, and a determination of the incineration conditions that will ensure the disposal of the waste in compliance with all applicable regulations. The steps taken to make these determinations constitute the process known as 'characterization of the waste.'

It is important to distinguish between characterization of the waste and analysis of the waste. Most industrial waste streams are complex mixtures so that an analysis is a very difficult and expensive procedure. The body of knowledge that is required for the characterization of the waste, on the other hand, can be considerably less detailed than that required for analysis. Although considerable attention is being directed to definition of those properties required for the characterization of an industrial waste stream, there is, at present, no unanimity within the technical community as to what constitutes an adequate listing of properties. The question of the basic properties of a waste that determines its incinerability will be treated below.

The selection of the most suitable incineration technology, once it has been determined that this is an appropriate disposal method for a particular waste material, has normally been based on the most immediately available system without regard to specific matching of the waste to the disposal system. In many cases a more efficient disposal can be achieved if an attempt is made to match the characteristics of the waste to those of the various incineration technologies. Ultimately, this final selection of the incineration technology should be made on the basis of cost-effectiveness coupled with the ease with which the disposal can be accomplished within full compliance with all pertinent regulations.

In order to match the characteristics of a waste to those of the available incinerators, and thus to select the most appropriate technology, it is essential that the physical properties of incinerators be known to a level of detail that will allow a direct comparison one to the other. The available information on such a system is primarily in the form of manufacturers' literature and thus can be expected to be somewhat non-objective. What is needed is an information base or document that will allow the enumeration of the physical characteristics, strengths, and limitations of the several available incineration technologies, plus specific examples of each technology. An information base that will allow a direct comparison of each system will, in turn, allow the selection of the most appropriate system for a given waste.

The situation with respect to air pollution equipment is essentially the same as that for available incineration technology. The needs for efficient selection of equipment to meet specific requirements are identical to those for the incinerators.

THE MULTI-TIER CHARACTERIZATION APPROACH

Required is a straightforward procedure by which a generator industry can define its waste stream and determine the necessary technology for satisfactory disposal and the costs of that disposal. A generalized decision matrix is presented in Figure 1, showing three major levels of decision, each level serving a specific purpose and each corresponding to a different point in the analysis.

The first tier characterization is designed to determine the suitability of the waste for disposal by incineration. This level of characterization requires the answers to at least the following questions:

First Tier Characterization - Suitability for Incineration

- Does the waste contain significant concentrations of metals that can form volatile compounds: Hg, Cd, As, Sb, etc?
- Is the waste such that incineration will not result in a significant reduction in bulk?
- Will there be significant concentrations of toxic materials in the residue?

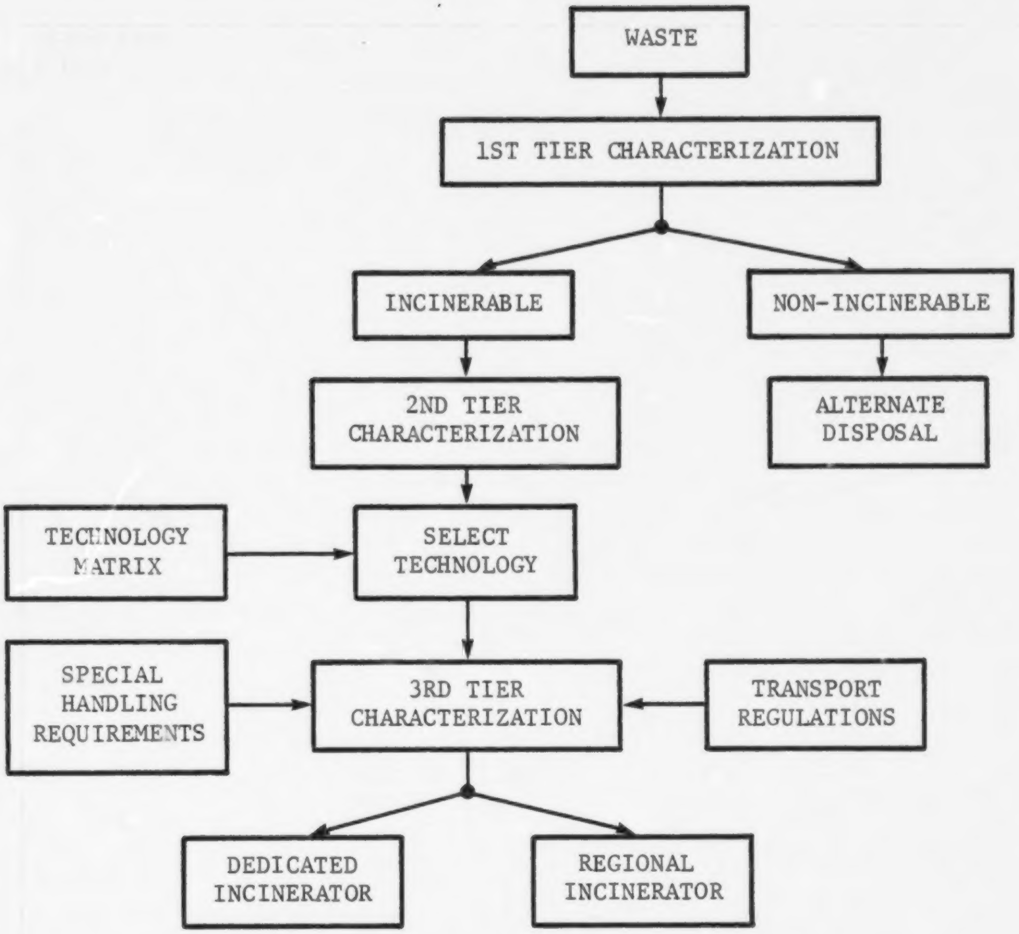
WASTE
1ST TIER CHARACTERIZATION
INCINERABLE
NON-INCINERABLE
2ND TIER CHARACTERIZATION
ALTERNATE DISPOSAL
TECHNOLOGY MATRIX
SELECT TECHNOLOGY
SPECIAL HANDLING REQUIREMENTS
3RD TIER CHARACTERIZATION
TRANSPORT REGULATIONS
DEDICATED INCINERATOR
REGIONAL INCINERATOR

Figure 1

Multi-Tier Characterization Matrix

If the answer to any of the above questions is yes, then the waste is probably not a suitable candidate for incineration and consideration should be given to land disposal. For those wastes for which incineration appears to be an acceptable disposal method, the characterization then proceeds to Level Two.

The second tier of characterization is designed to be used for the purpose of selecting the proper match of waste and incinerator technology. At the second tier it is necessary to introduce information on the characteristics of the available incineration technologies. The technology matrix might take the form as suggested in Table 1, where each of the identifiable technologies is listed along with its salient properties. Each technology would be identified by characteristics such as those listed below (not an exhaustive list):

Incinerator Characteristics to be Considered

- Suitability for various physical states of feed
- Ability to deal with residues
- Available residence time
- Available feed systems
- Maximum sustained operating temperature
- Suitability for auxiliary fuel
- Compatibility with Air Pollution Control (APC) Equipment
- Compatibility with corrosive materials
- Operating cost per unit thermal input per unit mass of feed.

The second tier characterization will be used to determine those factors and characteristics of the waste that determine the most suitable technology. The list of physical and chemical properties so determined would include (but not necessarily be limited to) the properties listed below:

Waste Properties to be Evaluated in Second Tier Characterization

- Physical state of waste
- Heating value of waste
- Presence of refractory compounds
- Time-temperature relationship for complete destruction
- Nature of combustion products
- APC requirements
- Possible disposal problems associated with APC operation
- Possible corrosion problems.

Table 1. Incinerator Configuration Matrix*

Technology	Physical Form			Residue		Residence Time			Nominal Temperatures		
	gas liq.	solid	semi-solid	none	significant	short	mod.	long	600°	1000°	1300°
Rotary Kiln	x	x	x	x	x		x		x	x	
Cement Kiln	x	x	x	x	x			x	x	x	x

*This sample table shows the manner in which kiln data would be compared.

When the data derived from the second tier characterization are compared with the technology matrix, it should be possible to select the most appropriate technology for the particular waste stream.

A major factor in the use of incineration as a disposal option is the determination of whether a dedicated incinerator is more cost-effective than relying on a large, multipurpose regional facility. The third level of characterization is used to assist in this determination.

At the third level of characterization those parameters that effect the decision of dedicated versus a regional facility are determined. In addition to the specific characteristics of the waste, there are also invoked special handling considerations and the relevant transport regulations. The properties of the waste that help determine this question include (but are not limited to) the items listed below:

Third Tier Properties

- Amount and rate of production
- Compatibility limitations
- Toxicity and hazardous nature of waste
- Location of generator relative public carriers
- Compatibility of combustion products to normal construction materials
- Special APC equipment requirements.

The additional information required to make the decision involves the nature of the special handling problems that arise from especially toxic wastes. Further, additional costs associated with the transport of especially hazardous materials would make an important impact on the decision for using a dedicated versus a regional facility.

Other factors that have not been directly incorporated in the above but which may provide a significant input to the decision of a dedicated versus a regional facility include the impact of local regulations and the local (public) attitude towards incineration.

CONCLUSIONS

It appears that a decision matrix approach can be constructed to allow the objective determination of the suitability of a given industrial waste for disposal by incineration, the most appropriate incineration technology, and the costs versus benefits comparison between use of a dedicated facility or a generalized regional facility. All this can be accomplished by a series of determinations of physical and chemical properties of the waste that should be significantly less costly than the more general practice of detailed chemical analysis of the waste.

INCINERATION TECHNOLOGIES FOR THE 1980's

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INTRODUCTION

It certainly is a pleasure to participate in this initial Conference on Innovation in the Environmental Technology Industry and, specifically, to serve on this panel. Certainly, technological innovation is vital to the health of our industry, but I would like to comment that all of these discussions won't be worth much if we can't get permits and sites for pollution control facilities. Efficient permitting strategies and protocols must first be established before any significant gains can be made in the application and implementation of advanced technologies, especially in the case of regional treatment facilities.

However, my charter this afternoon is to present a consultant's perspective relative to the types of emerging and innovative technologies that will be applied in the Toxic and Hazardous Waste Incineration Technology arena. Understandably, it will be somewhat difficult for me to confine my remarks strictly to a consultant's perspective, since subsequent to my accepting the assignment to serve on this panel, our company has been acquired by IT Corporation, an operating waste management company. Therefore, my perspective will probably reflect a blend of both viewpoints.

In considering how to address this complex subject in the limited time available, I have decided to focus primarily on the role of rotary kiln incineration systems. This is where the action has been taking place and is continuing to take place.

INNOVATIVE TECHNOLOGY FOR THE 1980's

The rotary kiln incinerator is a recognized "workhorse" for a broad waste profile. It is very flexible in terms of being able to accept a broad and varied waste profile. The total rotary kiln incineration system includes waste storage and pretreatment, kiln, the secondary chamber, energy recovery, and gas cleaning. This afternoon, however, I want to concentrate on the technology areas that are emerging in each of these individual unit operations.

A. Waste Pretreatment and Selection of Treatment Technologies

The combustion characteristics of incinerable wastes will continue to decline during the 1980's in both physical and chemical parameters, resulting in a proliferation of "dregs" from the chemical industry. For example, wastes of poor physical and chemical quality, highly chlorinated aqueous wastes in the form of sludges, would be representative of a typical class of industrial "dregs". Consequently, storage and pretreatment operations must be integrated in such a manner that the final waste feedstock blend is in optimal form for the selected treatment method. A first and central requisite is an advanced sampling and analytical capability. This characterization requisite is then coupled with treatment performance criteria and current market and economic strategies. Since different final treatment technologies may be used for similar waste profiles under varying market, economic, energy, and waste recovery climates, incineration technologies must be closely coupled to other waste management and treatment strategies including recovery, recycle, and alternative destruction technologies. This will also lead to the emergence of digital-type computer control instrumentation finding greater utilization in the total waste management decision process. The digital type of technology will also facilitate the recordkeeping required by the Resource Conservation and Recovery Act (RCRA).

B. Primary (Rotary Kiln) and Secondary Combustion Chamber

Although the rotary kiln has been utilized for the disposal of hazardous wastes for some time, kiln systems for the 1980's must be designed to withstand potentially more severe operating conditions. Specific areas are higher operating temperatures, effect of salt slags, strength of materials, and heat loss trade-offs. These areas come into focus on (1) refractory systems and (2) general kiln construction.

It is our opinion that for hazardous waste incineration systems, the refractory industry in the United States has only recently been motivated to give priority attention to optimal refractory systems that are suitable for long-term sustained operation under severe conditions. This becomes especially significant when the impact of higher temperatures and solubilizing salt slags are considered. The optimum solution does not lie in the selection of refractory alone, but in the total refractory system, which includes the protective slag layer on top of the refractory, the fireside refractory, the insulating refractory, and the refractory suspension system. The fragmented technology that is available in this country must be integrated and brought together in the 1980's and applied to develop realistic solutions within realistic time periods. Secondly, this technical service must become a permanent part of the United States refractory industry's scope of services rather than a periodic or one-time-only approach. If the United States corporations do not get their act together soon, someone else will do it for them.

The refractory systems in the secondary combustion chamber must tolerate the same basic conditions as the kiln refractory with the exception that (1) higher temperatures may be encountered due to localized radiant heat effects from the waste liquid burners and (2) slag protection of the refractory is not as feasible as in the kiln. In addition, since greater retention times are being suggested under RCRA, the effective height (or length) of the chamber may increase significantly. This places added emphasis upon the selection and design of the refractory suspension systems, which must consider trade-offs between heat loss and the cost of high-temperature alloy castings and face up to additional refractory support requirements due to added chamber heights. Again, the assembly of the total refractory technological data base in the format of an effective decision-making tool for incineration designers is a real and current technological challenge.

C. Energy Recovery

As the value of hydrocarbon fuels continues to escalate in the 1980's, energy recovery from the incineration of chemical "dregs" will become of more economic and political interest. The energy recovery systems, generally in the form of low-pressure steam boilers, must be capable of operating at flue gas temperatures of 2200°F and in atmospheres of anhydrous HCl vapor, salts, and metal oxides.

Heat recovery will be primarily by radiative heat transfer in order to cope with the slagging characteristics of the salts and metal oxides. Since radiation is relatively poor at these temperatures, large custom-designed boilers are necessary in order to extract the total heat load, resulting in correspondingly higher capital expenditures per unit of recovered energy. The need is to develop technologies that would reduce the capital costs of these installations. For example, through flue gas precooling by water injection, the physical characteristics of the slag-producing vapors can potentially be modified so that additional convective heat exchange can be utilized in place of radiative exchange without causing adverse effects on the completion of secondary combustion, or causing stress concentrations within the boiler or localized corrosion. The area of developing cost-effective energy recovery designs that are compatible with hazardous waste combustion products is in the emerging technology sector and will require solutions in the early 1980's.

D. Flue Gas Emission Criteria

As preliminary performance criteria are identified under RCRA, it is clear that existing flue gas cleaning system designs may no longer offer an acceptable solution for all operating situations.

1. Particulates

Several parameters are of significant interest. For example, a final particulate concentration of .08 gr/dscf at 12% CO_2 may be difficult to meet consistently for a broad waste profile unless very high-energy consuming scrubbing systems are utilized. Even in these cases, consistent compliance is doubtful. It appears that staged flue gas cleaning systems can be utilized to advantage in particulate removal. Of special interest is the wet electrostatic precipitator which appears to be capable of removing submicron particulates at low energy levels. It is anticipated that the wet electrostatic precipitator will find increasing application within the hazardous waste field during this decade.

2. NO_x and Burner Nozzle Design

NO_x emissions will continue to be of increasing interest and concern. As a result, specially designed waste burner nozzles mounted within specific refractory configurations will receive greater attention. For example, the degree of waste atomization, which determines waste/air contact, is an important factor in NO$_x$ formation, especially for nitro-containing wastes. Also, the atmosphere surrounding the burner flame influences NO$_x$ formation and general combustion quality. Much more attention will be required in the broad area of burner nozzle design relative to influencing the generation of undesirable emission products.

3. Scrubber Water Recirculation and Purge Treatment

Recirculation of incinerator scrubbing waters has not been widely demonstrated on broad waste profiles. The volume of scrubber water purge will be continually reduced, resulting in higher concentrations of salts and other by-products. Complementary treatment methods must be established, starting with reliable pH control, cooling of the purgeate, and finishing with physical and chemical treatment. The ultimate goal will be to eliminate the purge entirely, and remove all salts from the system as products of crystallization from saturated streams.

4. Dispersion Modeling

Predicting the point of impact of flue gas emissions, especially in areas of rapidly changing terrain, will receive increased interest and require the application of emerging modeling and dispersion technology. Of greatest importance is the need to identify the point of potential impact under a variety of atmospheric conditions, rather than only a definition of ambient concentrations. The point of impact should be described within a three-dimensional plane, rather than ground coordinates only. The objective is to identify any potential problem or complaint sources and effective trade-offs.

5. Flue Gas Monitoring

Finally, the technology associated with real time monitoring of flue gas emissions must receive priority attention in order to meet the intended degree of control expected to be required for many State and Federal permits. Many monitors are undependable and unreliable due to limitations in their sampling, calibration, and analytical subsystems. As a result, only a few of the measured parameters are reliable enough to be used for major process control functions. Top level technology, applied by highly trained and experienced people, is necessary to develop long-term solutions to this technological need.

E. Research and Development Activities

Incineration design and performance parameters, their definition, measurement, and prediction will receive paramount attention in the 1980's. In the next 5 to 10 years, the data base in this area will grow by several orders of magnitude. To develop this data base while minimizing environmental and toxicological impacts, reliable and relevant pilot incineration facilities need to be designed and constructed. The time could very well come when access to a well-designed pilot incineration facility will be required whenever the permitting and operation of a significant major incineration facility is contemplated. As a result, pilot units should be custom designed to reflect operating conditions in the full-scale incinerator system and to optimize control of all variables, including primary and secondary air, waste flow rates, temperature profiles, and flue gas velocities. A technological challenge in the 1980's will be the design of pilot incineration units with appropriate flue gas cleaning systems that can be used to generate a reliable and relevant data base for projecting design and performance standards.

For example, rotary kiln pilot plants can be used to determine combustion parameters and performance characteristics of liquid, solid, and sludge-type hazardous wastes as related to:

1. Rate of waste charging
2. Physical form of feed (liquid, solid, sludge)
3. Point and method of feed introduction into system
4. Sludge drying rates
5. Burn-out of ash
6. Flame stability at the burner
7. Impact of the degree of atomization at the burner
8. Impact of bulk and containerized feeds

These units are not small, being large enough to handle various sizes of containerized feed materials. With the accessibility to a model on-line pilot system, located alongside full-scale incineration facilities, a prudent and safe first step will be available for predicting the combustion characteristics of any new or complex waste profile.

CONCLUSIONS

Rotary kiln incineration system technology will play a leading role in the destruction of broad hazardous waste profiles in the 1980's. No other systems are capable of achieving such consistently high destruction efficiencies for varying and broad waste profiles. However, as with any mature technology, the process must be continuously optimized through a defensive research program. Pilot studies are required to investigate the relationship between a whole host of variables and to determine controlling parameters.

Formal training of incineration specialists is necessary for long-term process viability and understanding. During the 1980's the technology associated with the rotary kiln incineration of hazardous waste will advance by at least an order of magnitude in order to realize its full potential. In order to accomplish this objective, the leading universities of our nation must develop curricula that offer a series of sequential courses and a depth of training that will include combustion fundamentals and theory, principles of basic and advanced incineration design, practical experience, and research projects.

Only through this type of program will we be able to develop a cadre of properly trained people that will be able to plan and direct the technologies associated with thermal oxidation in the 1980's. This is a challenge not only to the universities alone, but to the pollution control industry and operators across the country.

HAZARDOUS WASTE INCINERATION TECHNOLOGY: THE FUTURE IN A REGULATORY ENVIRONMENT

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INTRODUCTION

The current Agency strategy places the highest priority on development of disposal technology and management criteria for hazardous and industrial wastes. As the quantity of these wastes increases, the need for advanced waste management technologies will become increasingly important. At the present time, thermal decomposition of hazardous wastes appears to offer the greatest advantage (relative to land disposal) for final disposition of these materials.

As we move toward implementation of the regulations for the Resource Conservation and Recovery Act (RCRA), there will be a very real need to have available performance data on a variety of thermal decomposition technologies. Not only are some technologies more efficient than others, but the question of waste stream compatibility with selected technologies must be addressed. Concurrently, a program of research and development for new and novel approaches to hazardous waste thermal decomposition should be established. There is likewise a need to evaluate necessary air pollution control technology and explore waste heat recovery opportunities in all potential applications.

Incineration is the process by which complex molecules are reduced to simple, inorganic residues which are nontoxic and nonhazardous. Thus, it appears that incineration is a final solution to the problem of the disposal of hazardous wastes. In spite of the seeming simplicity of incineration, there are many unresolved problems. In principle, incineration consists of exposing the target molecule(s) to a high temperature for a sufficiently long time so as to assure their reduction to simple oxides (and possibly to halogens or halogen acids). Inherent in this description are a number of areas of technology that must be addressed. Specifically, the following topics are of interest:

- The development of a public information program that will ease the present difficulties associated with permitting incineration (and land disposal) sites;
- The establishment of standard laboratory methods for ascertaining the suitability of a given industrial waste for incineration, for determining the conditions necessary for complete destruction of the waste, for determining the air pollution control (APC) equipment requirements, and for estimating the probable economics of the process;
- The establishment of emission standards for a variety of combustion products and residues including the generation of general and waste-stream - specific requirements on air pollution control (APC) equipment and standard protocols for performance measurements on such devices. Also required is development of suitable online

instruments and protocols that will assure the general public, as well as the regulatory agencies, that the emissions standards are being met;

- The development of systems capable of attaining the temperature and residence time conditions essential for the meeting of emission standards, which also includes further development of feed systems appropriate to a variety of physical forms that the wastes may take, and the development and testing of systems capable of extracting and effectively using the heat energy inherent in many industrial waste streams;
- The development of standard methods for scaling the results of laboratory and pilot-scale experiments to full-sized units;
- The development of criteria for the determination of the relative merits of large-scale, multipurpose facilities versus small, dedicated systems.

Each of these topics is treated in more detail below.

PUBLIC INFORMATION AND SITING CRITERIA

Most political jurisdictions are now requiring a public hearing before permitting a new or modified waste disposal facility. In large measure this is a natural result of an evolutionary process brought about by the complexity of the decisions that political officials are required to make. In order to dilute the ultimate responsibility, the public is invited to participate in the decision process. There are many dangers inherent in this process!

The quasi-judicial public hearing process has been developed as a mechanism by which parties with opposing views may come together to present their individual views and to reach a consensus. The petitioner for a permit to construct or to modify a hazardous waste disposal facility is expected to present his case in terms of the technical details of its operation, including the provisions taken to prevent accidents and the procedures to be taken in the event of an accident or other mishap. The public participants, who are usually opposed to the proposal, are expected to understand the presentation by the petitioner and then to present their position on the matter. In the dialogue that should follow, the points of difference should be accurately defined and subsequently resolved by compromise. Inherent in this mode of reaching an agreement is the existence of mutual respect and mutual trust as well as the absolute need for a common language.

A major difficulty arises from the very specialized vocabulary that characterizes much of modern technology. This language, which is specific to each of the disciplines involved, serves a very important function in that it allows precise communication between practitioners. However, the very nature of this language serves to confuse, and therefore frighten, the general public. Many examples of this problem may be cited - the arcane distinction between hazardous and poisonous will serve to illustrate the point. These precise distinctions are often lost on the lay public with the result that there is no common language, and thus a concensus is actually not possible.

Another aspect of the complexities of technical languages is the fact that, in the absence of accessibility to the technical literature, concerned laity must resort to the media for information and for understanding. Most of the media coverage of waste disposal has dealt with the coverage of the many incidents that have arisen because of improper waste disposal practices in the past. Many of the media presentations tend to the spectacular with gross oversimplification. Few of the commentators are sufficiently knowledgeable in chemical or toxicological technology to adequately appraise the actual situation. This fact, coupled with the very short attention span of both writers and readers, leads to the use of buzz words. Without an adequate explanation of the actual situation, the public reacts in an extremely negative manner, and the public hearings turn into only moderately controlled hysteria. If this situation is allowed to continue, there will be no new incinerators.

What is obviously needed is a careful examination of the present situation and the development of adequate and completely candid discussion of the past mistakes, both of commission and of omission. When such an appraisal is completed, it will then be essential that an educational program be undertaken to upgrade the general understanding of the problem of hazardous wastes, their sources, what the word "hazardous" actually means, how we intend to handle the problem in the future, and what that handling will require of the people and of the environment.

SUITABILITY FOR INCINERATION

The determination that a given industrial waste is a suitable candidate for disposal by incineration should be carried out in a series of steps. The waste must first be characterized in terms of its physical and chemical properties. Then, if the characterization indicates that the material can be disposed of by incineration, the necessary time-temperature relationships must be determined along with the required APC treatment for the control of emissions. Finally, the waste should be matched to a suitable incineration technology for its disposal. The later step may, if appropriate, include waste heat recovery. These steps are treated in more detail below.

Characterization of a waste stream is the first and perhaps the most important step in the certification that a waste is suitable for disposal by incineration. Most industrial wastes will consist of a large number of individual compounds so that a detailed chemical analysis would be excessively time consuming and costly. A partial analysis should, however, be carried out. Specifically, the waste should be carried through a proximate analysis for the determination of the elemental makeup. This stage of the analysis should include a metals analysis specifically for those metals that can form volatile compounds under the conditions existing in an incinerator. Those waste streams that contain significant proportions of such metals as mercury, lead, tin, zinc, arsenic, and antimony should not be incinerated (this could be altered if significant advances in APC equipment were made for the removal of the volatile metallic compounds from the combustion gases). The proximate analysis would also indicate something of the nature of the APC equipment that would be needed to control halogens, halogen acids, sulfur compounds, phospho-

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rus compounds and so forth.

If the waste stream does not contain significant quantities of the metals mentioned above, then the next step would be the determination of the existence of refractory compounds (those organic compounds that require high temperature and long residence times for destruction, with hexachlorobenzene as a typical example). There does not exist a standard protocol for this determination, but an experiment involving a small-tube ignition at an intermediate temperature (of perhaps 350-400°C) with the collection of condensible organics would suffice. The analysis of this condensate would then yield a catalog of those components that require high-temperature incineration.

The last step in the chemical analysis of the waste stream would be a high-temperature ignition to determine the type and proportion of the waste that will form the ash. This step is of significance in that it will determine the nature of the incineration residue that will require final disposal and may also determine the type of incineration technology required.

For those wastes that meet the criteria for incineration, it will also be of importance to determine the heating value of the waste. This is, of course, necessary to allow control of the incinerator during operation and in the possible employment of heat recovery.

The physical properties of the waste that are of importance are those that will determine the nature of the feed equipment that will be required for its safe handling (such as physical form and viscosity). The actual feed system needed is determined, in part, by the explicit incinerator technology employed; this aspect is dealt with in a later section of this presentation.

The practice in the past has been to determine the suitability of a given industrial waste for incineration by carrying out a series of experiments on an available incinerator. This practice is expensive and very restrictive in its applicability. The characteristics of every incinerator are specific to that installation, and, therefore, data obtained on a specific facility are not easily applied to a facility with a different configuration. In order to obviate the necessity of carrying out such test burns on every facility for every waste stream, a laboratory test facility was constructed at the University of Dayton Research Institute (UDRI) (1). This system, called the Thermal Decomposition Analytical System (TDAS), consists of a quartz tube placed in a high-temperature oven; the gas stream containing the sample under study is admitted to the temperature-controlled tube, and the decomposition products admitted to a mass spectrometer for detailed analysis. By variation of the oxygen content of the carrier gas, the temperature, and the residence time, it is possible to determine the thermal stability of a chemical species, the conditions under which it it degraded, and the degradation products that are formed.

The utility of the UDRI work was clearly demonstrated when their studies of the thermal degradation of kepone showed that the major intermediate decomposition product was hexachlorobenzene (HCB). Field studies of incineration as a disposal method for kepone (2) showed that, indeed, HCB was a major decomposition product. Further, the field tests verified the temperature-time relationships reported from the UDRI work.

The present configuration of the TDAS is somewhat limited in that there is no provision for obtaining detailed information on the simpler compounds resulting from combustion. Such a limitation prevents this approach to the determination of incineration suitability from yielding information relevant to possible special needs for APC. Further, there is no reasonable way for the present laboratory approach to give information as to possible economic considerations.

The limitations described above in no way diminish the utility of the TDAS as a preliminary screening technique for the determining of the suitability of a waste for incineration. It is recommended that, for the present, all incineration tests (large scale) be preceded by a similar TDAS test to determine thermal and time requirements. After the test burn has been completed, the findings of destruction efficiency as a function of exposure time and temperature should be compared to that determined in the TDAS. In this way, greater credibility in the results of the TDAS may be generated, leading eventually to the reduced need of pilot tests.

Perhaps the greatest utility of the TDAS lies in the ease with which a catalog of refractory intermediate and product compounds could be assembled. This catalog, along with the identity of possible intermediates, would then be used in conjunction with the characterization of the waste to define the necessary time-temperature regimen required for the safe disposal of the given waste stream. The use of the catalog would obviate the need to test every waste stream on the TDAS.

EMISSIONS

The most frequently asked questions at public hearings or in public discussions of hazardous waste disposal by incineration involve the emissions from such a facility. What are the emissions? Are they harmful? How will they be controlled? Are representative examples of the kind of public concern that exist available? It is clear that these questions reflect concern both for the facts and for assurance that the answers given are candid and correct. There are, therefore, two facets to the problem of emission control: (a) Development and characterization of the appropriate control technology; and (b) Development of methods and procedures that will serve to assure both the regulatory agencies and the general public that standards exist and that these standards are, in fact, being met.

As is discussed in more detail in the Scale Parameters section, the parameters that characterize an incinerator (temperature, O_2 concentration, CO/CO_2 concentration ratio, for example) are, by the nature of the measurement techniques, statistically averaged parameters. On the other hand, the precise steps by which a specific molecule is degraded to the final combustion products will depend on the actual conditions that exist in the immediate neighborhood of that molecule rather than the average conditions within the combustion chamber. Under these circumstances, the specification of a set of minimal operating parameters will not necessarily assure the control of emissions (of intermediates, for example) unless due care is taken to insure that the established minimum conditions include a generous safety margin over the actual minimum conditions as established, for example, by the Thermal Destruction

Unit (TDU). Alternatively, there must be available online instrumentation suitable for the detection of trace quantities of toxic materials.

Since there will always be some small fraction of the components of the feed appearing in the effluents of an incinerator, it is essential that there be established standards as to the allowable levels of these components in the effluents. There seems to have been a tendency, in the past, to set these levels at the detection limits of the most sensitive methods available. Such a practice would appear to preclude the use of onstream sampling and detection equipment since the most sensitive detection methods usually involve the extraction of the components of interest from large volumes of the effluent and subsequent analysis of the extract (which is itself subjected to further concentration). The fact that these steps are not taken in real time suggests the necessity of using secondary combustion parameters as measures of the efficiency of combustion in the system.

In the establishment of emission standards it is also necessary to recognize that very often the intermediates that can form due to improper incineration conditions might well be significantly more serious than the original material. This is well illustrated by the observation that pyrolysis of chlorobenzenes can lead to the formation of several of the chlorinated dibenzo-p-dioxins (3). Under these circumstances, it is obviously not sufficient to set an emission tolerance for the phenol species and to ignore the dioxins. Clearly, it is essential that there exist information as to the possible intermediates that can be formed from a given waste before suitable emission standards can be set.

The requirements on APC components are determined by the emissions that must be controlled (that is, the combustion products that must be removed from the gas stream) and by the allowable emission levels for these combustion components. A review of the available literature indicates that there does not exist a uniform standard by which such devices may be compared. What seems to be urgently required is a protocol which will allow a generally acceptable definition of "control efficiency" and which will determine such a parameter for any given APC device. Such a protocol should, ideally, be specific to the combustion components rather than to the technology utilized; this would allow the direct comparison of several technologies for a specific application. With specific emphasis on the combustion products, the protocol would then also address such problems as materials selection for corrosion resistance.

INCINERATION TECHNOLOGY

There exists a wide variety of incinerator configurations which have been employed for a wide variety of thermal processing. For the purpose of the incineration of industrial waste streams, there seems to exist no standard approach to the selection of a specific configuration which has characteristics that match those of the waste. It is our understanding that a catalog of available incinerator systems is presently being assembled. It is hoped that this catalog will be sufficiently complete so as to include the limitations as well as the advantages of each. The following questions could be used to characterize the match between the incinerator configuration and the proposed waste stream:

- Is the incinerator configuration compatible with the feed requirements of the waste?

- Is the incinerator configuration compatible with the temperature-time regimen required by the refractory components of the waste?

- Is the incinerator configuration compatible with the residues that result from the waste?

- Is the incinerator configuration compatible with the corrosive combustion gases from the waste?

- Is the incinerator configuration compatible with the APC requirements of the waste?

- Is the incinerator configuration compatible with possible heat recovery from the waste?

- Is the incinerator configuration compatible with the required (proposed) feed rate?

It would appear that the above set of questions might well be used to settle the question of the selection of a suitable incinerator configuration for any given waste stream.

One aspect of incinerator technology that appears to have been underdeveloped is that of feed mechanisms for hazardous industrial wastes. A detailed catalog of the available systems would be of great help in defining the magnitude of this problem. Literature available from manufacturers represents such a wide variety of format and such a variation in quality and accuracy that it is very difficult to make comparisons. A compilation by an outside agency would be of great value; especially if it were to specifically address the following points:

- Range of feed rates

- Range of physical states (solids, semisolids, sludges, etc.) and viscosity for which the system can be used

- Compatibility with different incinerator configurations

- Compatibility with stringent safety requirements

- Compatibility with corrosive materials

- Waste stream container limitations, if any.

There is also the problem of the containerization of the waste when it must be shipped from the point of generation to an incinerator facility. There seems to have been little direct effort expended on the technology required to safely open sealed drums and to subsequently remove the contents for incineration. This area urgently needs additional effort.

SCALING PARAMETERS

There exists a variety of models that describe the mass and energy flow in several incinerator configurations; several of these models have been confirmed to an extraordinary degree. On the other hand, estimates of the effect of changing scale on the production of intermediates, and thereby on the nature of the required APC equipment, are considerably less successful. The fact that there does not exist a practical prescription for determining the properties of a large system by scaling the observed results from a pilot system has made it necessary to rely on the costly approach of test burns when an incineration system is scaled up. It is clear that the availability of an accepted and verified method for estimating the effect of changes in size would be of great practical value.

In order to understand the nature of the problems that are associated with scaling it is essential to focus on the combustion process itself. The following brief discussion will focus on those materials that are not flammable; this narrowing of the problem is useful since it results in the division of the thermal processes into two categories, namely, the initial conversion of the material into the gaseous state and the subsequent gas-phase reactions. The former phase can be rather well dealt with in scaling using available models for energy and mass transfer. The precise nature, or more exactly, the statistical nature, of the gas-phase reactions will ultimately determine the nature of the intermediates and the final combustion products that are formed.

Normally, it is understood that scaling up of an incinerator involves simply the increasing of the volume of the combustion chamber (and increasing the rate of injection of waste material and energy). It would then be expected that, if the temperature and the residence time were identical between the pilot system and the scaled-up version, the composition of the combustion gases should be the same. The failure of the scaling procedure lies in the observed fact that the composition of the two gas streams is, in fact, often not the same.

The nature of the problem may be addressed by enumerating several facts:

(1) Each molecule in the gas phase has available to it a number of alternative paths by which it is ultimately degraded;

(2) Each pathway and each intermediate step in that pathway proceeds at a rate that depends on the local temperature;

(3) The rate of each step of a given pathway also depends on the composition of the gases within the elemental (local) volume immediately surrounding the target molecule;

(4) The temperature, as recorded on a thermometer, is an average that is defined only for an equilibrium system; and

(5) Despite the extreme turbulence (deliberately introduced so as to

insure complete mixing of the fumes) within the combustion chamber there is no justification for the assumption of local equilibrium.

As a consequence of the facts enumerated above, there is little reason to expect that the degradation pathways followed by each molecule are the same. Further, when the volume of the chamber is altered and the energy input increased, there is no reason to expect that the localized conditions will approximate those that exist in the smaller system.

The Parametric Investigation of a Field Scale Hazardous Waste Incinerator (4) has been designed to determine, among other parameters, the nature of the quantities of intermediates that are formed during combustion of refractory organic compounds. The information that will be derived from these studies will serve to indicate, by the relative concentrations of the intermediates that are observed, the relative probabilities for the target molecule to take the specific pathway leading to the formation of that intermediate. This information coupled with the measured residence time and the measured temperature should form the basic information upon which to construct a model of the combustion processes and the dependence on the precise local conditions within the incinerator.

A model that can successfully deal with this type of scaling situation will necessarily take the form of a stochastic description of the available degradation pathways and their temperature dependence. The resulting model must then be smoothed so as to yield additional averaged variables suitable for direct onstream measurement. That is to say, it appears that the present difficulty with scaling lies in the inadequacy of the parameters that are specified as the scaled parameters.

DEDICATED VERSUS REGIONAL FACILITIES

It has long been recognized that scaling economics may be obtained by the uses of large, multipurpose incinerators receiving wastes from a number of generators. Such is the practice in many of the European countries, and such has been the practice for a number of United States firms. It would be very appropriate at this time to devote some effort to a consideration of the factors (other than costs) that would influence the decision to construct more such general facilities rather than permit small dedicated facilities at the site of generation. Such a study should address the following points:

- Is a large-scale facility more economical than a dedicated system?
- What is the hazard of shipping to a central facility, and how does this effect the economies, if at all?
- What is the hazard of incinerating mixed wastes, and what criteria should be used to determine compatibility?
- To what degree will the public accept small dedicated facilities that are part of an industrial complex as compared to a general facility receiving wastes from many sources?

- To what degree does the minimal need for characterization of the waste for a dedicated incinerator compensate for the probable increase in operational costs?

- To what degree would the proliferation of dedicated incinerators complicate the regulatory problem?

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Question (Jack Yost, Purdue University): One of the panelists indicated that he had some experience with metallic industrial sludges, and in particular I would ask whether or not these would be metal hydroxide sludges; if so, how well do they process through the incinerator facility in question? Or did I misunderstand?

Response (Richard A. Carnes): I don't think I raised the word, but I would comment this way: The metal content of a material is something that is very closely watched. As a point of fact, we don't consider metal oxide sludge as being amenable to incineration.

There certainly are cases where metallic materials or something else do get into the process and then it becomes a matter of determining the ash content and working it out from there.

Response (Rudy G. Novak): That explains it. The reference that I made was to the presence of metal materials in incinerable waste and their fate in the incineration process, and to the extent to which they get into either the ash or the scrubber water, they have to be dealt with. But I wasn't referring specifically to the incineration of metal oxide or metal hydroxide sludges. As Jack has said, you would not normally consider them candidates for incineration.

But you do get a lot of organic wastes that contain metals that are going to end up either in the scrubber water or in the ash from the incinerator.

Question (Jim Basilico, EPA, Research and Development, Washington): One area that we seem to have brushed over is resource recovery. I know you talked about heat recovery, but I think a lot of our waste substances are chlorinated hydrocarbons and many of those materials are as high as 70 to 80 percent chlorine on a mole weight basis. When you incinerate those materials, you are going to end up with hydrogen chloride.

Is there any consideration under certain local economic conditions to recover HCl, hydrochloric acid? There is also potential for resource recovery of hydrogen chloride, once one of the main raw material sources for producing chlorine. The Decon process, which used hydrogen chloride, when oxidized with oxygen produced chlorine. That was the method of production in Europe and in this country until about 10 years ago.

That's another area for resource and recovery.

Is there any consideration for those types of recovery schemes?

Response (Richard A. Carnes): Those particular approaches were certainly looked at. One key factor, it's very rare that a waste stream is subject to a commercial firm for handling incineration until it has knocked on every known and established door that can provide some type of recovery service.

Once that has been done, you are still dealing with the material, and it does not matter whether it comes from a relatively clean set of solvents or some very complex still bottom. You can still produce the HCl in the stack. One of the things that slows it up is that everybody wants to see what the standards are going to be before they make additional million dollar incremental investments for the recovery.

In terms of HCl, one of the big problems is that it is such a market-sensitive material. The prices go up and down. You certainly have problems with this product. There are some other chloride materials which we look upon more favorably as possible recovery items. I think that they will primarily be implemented after final incineration regulations are in place.

The driving force will be cost-reduction program in the operation of the facility, rather than because of the economic incentive for recovery in its own right. It will be that cost reduction element.

Chairman Whitmore: Any other comments or questions? If not, we thank you for your attention.

Summary Comments (Chairman Reznek): Thank you, I would just like to say that I enjoyed this morning's session and to summarize the conference's work up to now.

The air pollution session certainly gave the impression that there is action underway, that the types of pollution and the technologies are changing.

The water pollution sessions, both in the industrial area and the municipal area, left me feeling -- though some people in the audience disagreed with what was presented -- that the technologies are basically there, and that they are not going to change a lot.

The last session, on hazardous waste incineration, is clearly a technology that we do not yet know how to characterize. The cost per performance, in terms of individual molecule destruction, is beyond the state-of-the-art at this time. Yet EPA and the country are faced with trying to bring about a technology without as much understanding as there is in, say, the water case, and to deliver this technology to meet a very important national need. At the same time we are trying to learn more about the technology so that in fact we know what the cost versus performance curves look like so that we can begin to innovate.

Session III

Administrative and Institutional Factors in Technology Innovation

Presiding Chairman:
John Quarles, J.D.
Attorney
Morgan, Lewis, and Bockius

INTRODUCTORY REMARKS

John Quarles, J.D.
Attorney
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My name is John Quarles and I am the presiding chairman for this morning's session on Innovation in the Environmental Technology Industry.

I think you are all familiar with the overall dynamics of the environmental regulatory program. Nonetheless, I think it is worth stressing that we are progressively in a phase in the overall national pollution cleanup effort where the central importance of research and improved technical and scientific understanding of environmental effects increasingly dominate the center of the stage. This involves improved methodology for measuring, calculating, and predicting environmental effects and for improved technology for the control of pollution -- all technical and scientific parts of the total cleanup effort. This phase is in distinct contrast to the circumstances that existed a decade ago. At that time, we had more severe pollution problems and less knowledge of how to solve them -- less total knowledge about them. The outstanding feature of the American Situation then was that we were not doing those things that obviously could have been done to reduce the impact of pollution on the human environment.

The chief ingredient lacking was the determination of national will to move forward with antipollution work and the creation, therefore, of regulatory impetus to make it a first priority. In the early years of the U.S. Environmental Protection Agency (EPA), from 1970 through the beginning of 1977, during which time I served as first General Counsel and Head of the Enforcement Program and then as Deputy Administrator, there was woefully little attention given by top policy officers to the whole research and development (R&D) budget and to the interaction between the technical side of the agency and the regulatory and operational side.

One of the great achievements of that era was the force put on the regulatory and operational side to move ahead with the implementation of the technology then available. But we were living off the capital that had been accummulated over the decades.

At least, from top level Government very little was being done to explore the mechanisms that can contribute to the improvement of technology or to tie in closely the ultimate needs of society to the channels that can provide the technical expertise to meet those needs. By now such a complexity of the regulatory programs has developed that, literally, they are almost overwhelming. At the same time, an emerging recognition has also developed of the need to go back to basics. Look at the scientific knowledge that will be necessary to enable society to tackle a new generation of more complicated environmental problems.

ALTERNATIVES TO CONVENTIONAL POLLUTION CONTROL

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Early in the 1970's, a television manufacturer suddenly found himself staring in the face of a couple of problems. The fees he had to pay for wastewater handling to a sewage treatment system had started to move right off the chart. At the same time, costs of clean process and drinking water were rising sharply as well. Water, which had been more or less taken for granted until that time, had become an issue. It began to draw management's attention. As a consequence of this stimulus, the company took a close look at its use of water. Changes were made--small changes. And by 1975, the use of water at four plants had been cut by a fifth. Nearly a billion gallons of water a year--water that had been obtained, used, and later treated--were no longer used and treated. Today water consumption is down by a third.

How was it done? First, the company stopped cooling machines and engines when they were not in use. Second, the company installed thermostatic control valves and began to regulate the temperature of cooling water. Water no longer drained off automatically when its temperature rose by two degrees. It was drained when it got too hot, not any sooner. The additional valving and instrumentation rapidly paid for itself. The company was Philips in The Netherlands.

In the 1974-1975 recession, a major diversified manufacturing company faced profit erosion. Top management asked the departments to propose ways to trim off avoidable expenses. The company's environmental department said that it couldn't do much to help. "If we don't spend the money," they said in effect, "you folks will go to jail. Once the other departments make the pollution, all we can do is clean it up." Top management said in effect, "Why don't you look at the processes and get rid of the waste?" Thus was born a successful program of waste elimination.

Five years and 126 projects later, the company had saved nearly $22 million. Most of the savings were realized because the company did not need to build so many black boxes at the end of the pipe or vent stack to treat effluents. The company was 3M and the program is called 3P--Pollution Prevention Pays.

Late in 1973, a manager at a textile mill called in a consultant. The manager had a problem--and an idea. The company operated a textile dryer which was fired indirectly. Fumes emitted by the drying textiles caused an air pollution problem, and the dryer consumed purchased fuel. This was the problem. As for the idea, the manager wondered if the fumes from the dryer might not be burned in the combustor--eliminating pollutants while simultaneously capturing the heating value of the fumes. The consultant went to work and developed a solution. Nowadays the fumes supply 60 percent

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of the energy to the dryer, the company spends $67,000 less a year on purchased fuel, and air pollution has been stopped. The solution took some fancy engineering, supplied by the Marshall and Williams Company. The textile manufacturer was Kayser-Roth.

* *

These three cases represent what might be called alternatives to conventional pollution control. In each case, one or more problems in pollution control were dealt with in a novel way--usually by changing something in the process so that it produced less waste in the first place. In each case, economic and regulatory pressures caused management to focus on some operation. In every case the solution lay hidden in the situation, waiting to be found. The situation had to be understood in a new way. The system needed study. But once technical resources were brought to bear, innovation took place. In two of the cases the technical staff that solved the problem came from within the company; in one case a consultant worked out the answer. But in all the cases I have cited, the idea for the innovation came from those directly involved with the process.

These cases come from a study we have just completed for the U.S. Environmental Protection Agency. Such innovative approaches, such alternatives to conventional pollution abatement, have always played a role in environmental control. They represent an economically more efficient way of protecting the environment than scourging effluents with energy in special purpose chambers that cap the stacks or plug the sewer pipes of industry. Was process optimization--for purposes of pollution control--a well-developed technology capable of wider use? Was it universally applicable, or just in special cases? Did all companies make use of such strategies or was it the exclusive domain of the giants? Was process optimization a growing or a fading phenomenon? Did each case demand a breakthrough? And what about the economics?

We set out to find some answers. We had discovered that people in environmental protection all knew of such cases. Certain aspects of process or system optimization--such as water conservation, for instance--were even documented fairly well. But no one had assembled a fair number of different types of cases, looked at them, talked to people involved in the process of innovation, and produced a reasonably thorough overview. EPA needed such an overview, and we carried out the job.

* *

What did we discover?

It might be well to start with the big picture. The U.S. Department of Commerce has been collecting data on what industry spends on pollution control. Statistical series for the years 1973 through 1977 exist. These data leave much to be desired, but they are the best we have, and fortunately the Census Bureau has asked industry to report separately capital spending on end-of-the-line equipment and on pollution-related process changes.

The data for all manufacturing industries--and that excludes utilities and railroads--show that capital spending on process change was almost 10 percent of total outlays for pollution control in 1977--$320 million of a total of $3.3 billion. (The percentages for air and water, taken separately, are the same.)

The proportions have not always been the same. They have dropped from 16 percent in 1973 to 10 percent five years later. But they won't necessarily stay so low in the future. There is some very circumstantial evidence to show that spending on process-related solutions moves up just ahead of legislative deadlines and then softens after the deadline passes.

It will come as no surprise to you that industries that do a lot of processing put disproportionately more absolute dollars into process change than others. Producers of chemicals, paper, petroleum and coal, primary metals, and food account for about 43 percent of manufacturing shipments but for 80 percent of expenditures on process change. The chemicals industry, with 9 percent of shipments, accounts for 33 percent of process change dollars.

These figures explain a perception we encountered--namely, that large companies are more innovative and are more likely to use process change as a pollution control solution. We do not believe that that is true. But much more is spent in the process industries, which are old and mature and hence dominated by large companies. Innovation along these lines goes on everywhere, in companies of every size. But the programs of small companies are less visible--because they are small.

* *

If process change and optimization offer substantial savings--which seem to be lying about, waiting to be discovered, like money on the street--why does industry only spend between 10 to 20 percent of its pollution dollar on such profitable changes in the plant? Could all expenditures on terminal black boxes be eliminated if only industry tried harder?

Based on the cases we have studied--all of them drawn from technical literature published between 1974 and 1979--it would seem that much more could be done. Some companies have discovered the strategy of process change in the 1950's. Others have stumbled across it just the other day. Yet others have not yet discovered the benefits of systematic process modification. There are institutional barriers here, and I shall outline those briefly in a moment. But first another point.

It seems that much more could be done; but for the present, anyway, changes in manufacturing processes will not altogether eliminate the need for scrubbers and precipitators, baghouses and aeration lagoons, filters and polishing ponds, activated sludge treatment or columns of activated carbon. There are both technical and economic constraints that presently impede total recycling of residues and zero discharge of pollutants. Eventually, of course, as economic and regulatory pressures continue to stimulate adaptation, more and more of the terminal treatment system will become "internalized," as it were. Tail-end systems will become front-end systems--producing raw materials and process water. Their justification will change--is changing. They will be installed--are being installed--to capture resources rather than to keep the boss from wearing a striped suit. But we are not there yet. And even in the long run, there will be residues.

The question we struggled with during this study is a question of degree, not of absolutes. How much of a potential is out there--unfulfilled? In the two cases we found where the innovators provided enough information to compare a process change solution to a tail-end solution, $1 of end-of-line expenditure was eliminated by spending 75 cents in one case and 20 cents in the other. That sort of thing is attractive. It would be nice to know how many such cases are out there now slated for conventional solutions.

The same difficulties that impede process optimization kept us from answering the question. The opportunities are out there, but they are not like money on the street at all. They are hidden and cannot be counted. They reveal themselves only upon investigation--often difficult and risky investigation. People do not embark on such chores unless they have to.

* *

This brings me to my next point. Why do people innovate?

It seems to be because they have their backs against a wall. The conventional solution costs too much.

Pollution control is still viewed by many people in industry as something nasty and unnecessary imposed by a capricious and malevolent authority with the sole aim of frustrating the innocent gathering of berries in the garden of free enterprise. And if you have ever plowed through reams of regulations in the frugal small print of the *Federal Register*, you will sympathize with this attitude.

Put in less exotic language, many people in industry still view pollution control as an externality, not as an inherent and necessary resource of production. This attitude often prevents a search for opportunities, at the company's own initiative, to optimize the pollution abatement system. The impetus still comes from the outside--a rise in costs, a regulatory deadline, local complaints about the factory's seductive smell. And so long as a conventional solution is "reasonable," the conventional solution will be bought. It's the way to do it. The black box may be expensive, but it won't interfere with the process--much. The process is the company; the control system belongs to the "enemy."

I am exaggerating, of course, in order to make a point.

The point is that process optimization today still tends to be a problem-solving rather than an opportunity-seeking activity--although, once tried and found to be profitable, its character can change. The first time around, it tends to be examined as a possibility only as a last resort.

* *

If now we look across the river to see how the regulators are behaving, the picture does not exactly brighten.

The entire Federal strategy is built around terminal control. The industrial world simply mirrors the legislation and regulations issuing from Washington. Both the Clean Air and Clean Water Acts contain waivers for innovation, but these are still not comprehensive enough, in industry's view, to stimulate innovation. The Clean Air Act applies only to new sources. The Water Act does not provide flexibility enough in the timing of compliance to excite the permit holders. Innovators must also show that the alternative has applicability across his entire industry; site-specific solutions are thus taboo. At the same time, regulatory virtuosi are writing ever more complex symphonies of compliance, with intricate timing and subtle beat, and industry must produce an ever larger orchestra to play the music. Who has time to think, to innovate?

Time, above all, is a problem. Optimization frequently demands more time than does the purchase of conventional technology. Since the process of optimization is less predictable and more risky, the company must decide which route to follow at a point in time when there is still time enough to comply by the conventional method. The time requirements of compliance thus sometimes force abandonment of a promising alternative because there is no time to explore it fully or, more commonly, the company does not even consider optimization because there is too little time to do so.

Companies also report a disinclination to innovate because they fear that today's process change, sufficient to avoid today's terminal control, will be imposed by rule tomorrow--in addition to the terminal control. A mousetrap may be cheaper than a cat; but a mousetrap, a cat, and a quantity of rodenticide will do an even better job. "Why not all three?" the regulators ask. "Why invent a mousetrap?" says industry.

*　　　*

As you can see from these brief sketches, there are institutional problems here that work against the identification and use of alternative solutions.

There are also forces that favor process and systems optimization.

On the regulatory side, the bubble concept is seen by industry as the first dawning of rationality in the small brain of the dinosaur in Washington. Industry wants flexibility and freedom to optimize within a larger sphere--the larger the better. It would like to see more consideration of technical and economic realities and less emphasis on regulatory designs that facilitate monitoring for compliance. The bubble promises a shift in emphasis.

The rising costs of control by conventional methods, new legislation closing off the last of the cheap solutions (I have in mind the hazardous waste rules issuing under the Resource Conservation and Recovery Act), more sophisticated management of the environmental control functions in industry, and the costs and uncertain supplies of energy are all factors that tend to stimulate the search for alternative solutions.

Let me elaborate on two of these factors--management and energy.

The avalanche of complex environmental control regulations and, of course, the high costs of compliance have caused substantial increases in the number of people in industry whose full-time job is the environment. Along with this increase in numbers has come a centralization of the function.

Management of the activity is now also at a much higher level in the corporate structure. In a word, industry's management of environmental affairs has become sophisticated. With this has come a shift from reaction to anticipation. Documentation of past expenditures is being replaced by prediction of future costs of compliance--even for legislation that has not yet passed. Corporate management today has an early warning system.

Environmental staffs are trying hard to persuade line managers to act early, by prevention, in order to avoid the much more costly cure of terminal control later. Environmental managers in industry are often frustrated with the heedless apathy of operating departments, which do not reflect this new attitude uniformly. But someone is trying and pushing from within. These elements in industry are also sending out some new and novel messages--that cost avoidance can also lift return on investment; that optimization of pollution control *is* process optimization; that pollution control is a given and needs to be managed like any other input to the process.

The energy crisis resembles pollution control in that it has imposed new costs substantial enough to get top management's attention. Energy management influences pollution control by optimization in two ways. First, terminal control systems tend to require a lot of energy to operate and thus become a natural target of conservation programs. Second, the way one goes about cutting down on the use of energy is identical with the method used for process optimization. Both require a new look at the process--a restudy of the whole and of its components, a questioning of long accepted practices. Thus energy conservation and optimization in pollution control have stimulated one another.

*   *

I now come to my last key point. Is optimization a technology? Can it be transferred? If the answer to these questions is yes, then this "technology" is likely to spread as it develops and as the market environment favors its use.

Process optimization is not a technology in the same way as, for example, electrostatic precipitation is. It is not an item you can go out and buy. But it is a technology in the sense that it is a method of analysis, planning, and implementation that can be applied in the same way over and over again. Those who have learned it can do it again--and usually do. They can teach others--which they seem to do much less frequently.

Terminal control is equipment looking for a situation.

Optimization is a situation looking for equipment.

The real key to optimization is that it is a problem-solving methodology that requires both managerial and technical initiatives. It demands a decision to look for an unconventional solution. It demands technical imagination to envision a new solution. Once the idea has been formulated, the rest of the job can be handed to others. If the idea has wide applicability in the industry where it arises, it becomes transferrable. The originating company, in fact, will most likely try to license its use. If the solution is based on unusual conditions at the site, it will not be transferrable.

The answer to the questions I posed earlier can thus be a qualified yes. Yes, process optimization is a technology. The method is transferrable; the results are sometimes transferrable. Each case requires initiative and imagination.

Our cases show that initiative and imagination are especially stimulated by trouble. We are likely to have a more than adequate supply of that commodity--and that makes me sanguine about the future of innovation in pollution control.

Foreign Technology Exchange

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JAPAN'S AIR POLLUTION CONTROL, CONTROL TECHNOLOGY, AND PROBLEMS

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ABSTRACT

Stringent SO_2 regulations in Japan, with extensive monitoring using automatic analyzer-telemeter-computer systems along with SO_2 levies imposed on industry, have resulted in construction of over 1,200 flue gas desulfurization (FGD) plants and a remarkable decrease of ambient SO_2 concentrations to meet the ambient air quality standard.

NO_x has been reduced by means of extensive combustion modification at numerous stationary sources, by selective catalytic reduction (SCR) of NO_x, and by the most stringent control of automobile exhausts.

The quality of the control technology has been significantly raised. FGD systems have become so reliable that nobody installs a standby scrubber. Most SCR plants are trouble free, enabling unattended operation. NO_x emissions from new passenger cars were reduced from 0.6 gram/kilometer in 1976 to 0.2 gram/kilometer in 1978 with gasoline consumption reduced by 5 to 15% in the same period.

Despite all this success, Japan's air pollution controls do have considerable problems. Many of the FGD processes developed are fairly costly and cannot readily be applied to other countries. Ambient sulfate concentrations decreased remarkably between 1970 and 1973 and have since started to increase slightly in spite of the continuous decrease of SO_2. The number of designated air pollution patients has increased.

There may be uncertainty still about what are the real important air pollutants. Secondary pollutants such as sulfates and photochemical oxidants may be more hazardous than primary pollutants such as SO_2 and NO_x. Particulates emitted from stationary and mobile sources include numerous substances with a variety of particle sizes, some of which may be very hazardous while others may not be. Further studies are needed to find out the best way to prevent pollution. Although control of primary pollutants is necessary, the control technology should be improved based on the studies.

SO_x CONTROL AND PROBLEMS

In order to cope with the serious air pollution caused by the rapid industrial growth since 1960, the Japanese Central Government set stringent standards for ambient air quality (Table 1) and also for emissions. In addition, local governments have set even more stringent regulations based on ordinance and agreement with industry. In order to ensure the abatement of pollutants, local governments have conducted extensive monitoring using automatic analyzer-telemeter-computer systems for both ambient air quality and emission concentrations.

Table 1. Ambient Air Quality Standards (ppm)

	SO_2		NO_2	
	Daily	Yearly	Daily	Yearly
Japan	0.04	0.02	0.02[a] 0.04-0.06[b]	0.01[a] 0.02-0.03[b]
U.S.A.		0.03		0.05
West Germany		0.05		0.05

[a] 1973-1978 [b] Since 1979

Desulfurization of fuel oil and flue gas started in the late 1960s. At the early stage of the development of flue gas desulfurization (FGD), most utility power companies were reluctant to adopt it because of the uncertainty in the reliability and instead reduced SO_2 emissions by changing fuels to low-sulfur oil and natural gas. Industries which suffered from the shortage of the low-sulfur fuels had to install FGD plants. Some of the FGD systems encountered problems at the beginning necessitating the shutdown of the gas sources. Under such circumstances, both process developers and users worked hard to improve the FGD processes, and have succeeded in establishing reliable technologies.

As shown in Figure 1, FGD plants started to increase rapidly in 1972, and the yearly production of the plants reached a maximum of 150 billion yen (680 million dollars) in 1974. The total number of FGD plants has exceeded 1,200 with a total capacity of nearly 50,000 MW equivalent. Many plants for hydrodesulfurization of fuel oil were also constructed. The yearly production of the hydrodesulfurization plants reached a maximum of 75 billion yen (336 million dollars) in 1975.

The driving forces for the construction of many desulfurization plants were as follows: (a) Stringent regulation and extensive monitoring; (b) Establishment of technologies; (c) Governmental assistance for industry by providing low-interest loans for the construction of pollution control facilities; (d) Rapid industrial growth between 1965 and 1975 which enabled industry to invest extensively for pollution control; (e) Shortage of sulfur and its compounds which has made FGD byproducts useful.

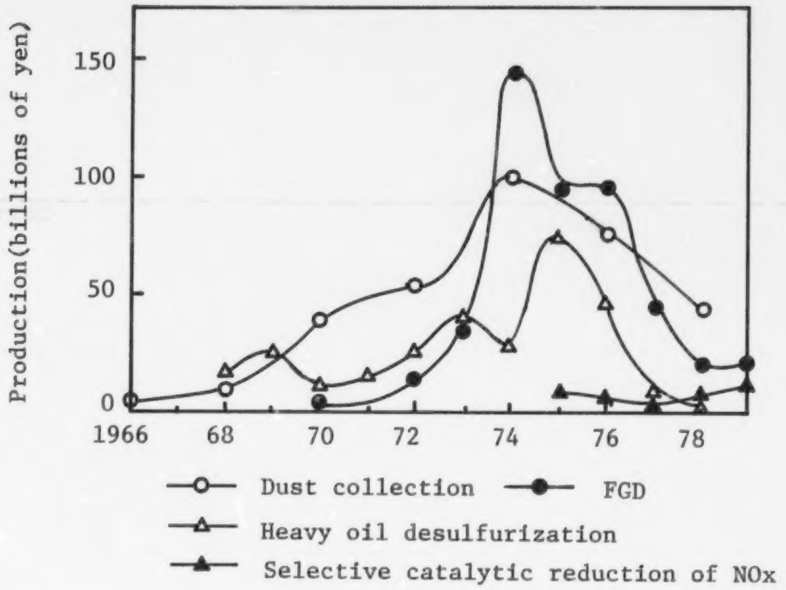

Figure 1. Yearly production of air pollution control facilities

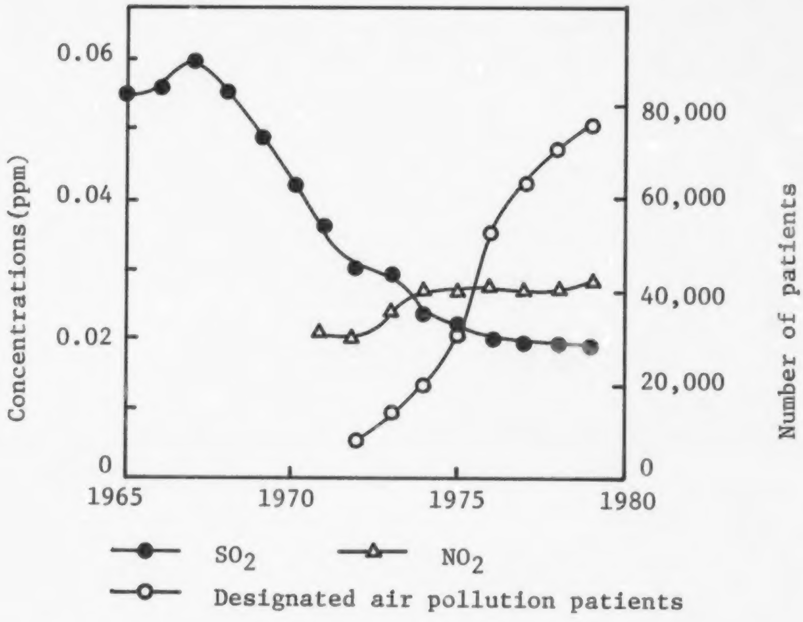

Figure 2. Ambient concentrations in yearly average in 15 major cities and industrial regions and number of designated air pollution patients

By the desulfurization efforts along with import of low-sulfur fuels, the ambient SO_2 concentrations have decreased remarkably since 1967 to meet the stringent ambient air quality standard (Figure 2). Yearly production of desulfurization facilities decreased after 1976 because of the decrease of the SO_2 concentrations, economic depression, and oversupply of FGD byproducts. The yearly production of FGD plants dropped to 20 billion yen in 1978 and then started to increase gradually because of the recent increase in the use of high-sulfur oil and coal, due to the shortage of low-sulfur oil.

Another driving force for SO_2 abatement has been the SO_2 levy applied since 1974 to SO_x sources in designated regions emitting flue gas more than 5,000 Nm^3/hr (1.7 MW equivalent) and in other regions emitting more than 10,000 Nm^3/hr (3.4 MW equivalent) (Table 2). The owners of the SO_2 source have to pay the levy according to the amount of SO_2 emitted even though their emission is low enough to meet the regulations. The levy has been used for the relief of the patients in the regions, who have been diagnosed by a medical doctor as air pollution victims. The designated regions, which initially covered only heavily industrialized regions, have been expanded to include considerable parts of large cities such as Tokyo and Osaka, resulting in the remarkable increase of the designated patients, contrary to the decrease in SO_2 concentrations (Figure 2). As a result, the levy rate (yen/Nm^3 of SO_2) has increased tremendously as shown in Table 2. Some of the industries tend to install FGD plants to reduce the levy even though their SO_2 emissions are low enough to meet the regulations. Such efforts, however, further raise the levy rate, as long as the number of patients does not decrease.

Table 2. SO_2 Levies (yen/Nm^3 of SO_2)

Regions	1974	1975	1976	1977	1978	1979
Osaka, etc.	16	37	210	536	774	1,239
Tokyo, etc.	16	37	210	381	430	646
Chiba, etc.	16	37	210	345	344	517
Omuta, etc.	16	37	210	307	301	452
Other	2	9	23	34	48	72

Such a situation has caused political problems. Industry claims that because the ambient SO_2 concentration has decreased, the designated regions should be reduced so that the number of the designated patients will be reduced. Conversely, some people claim that the increase in the number of patients has been caused by NO_x and want to have more stringent regulations on NO_x, including NO_x levies, and to designate NO_x-rich regions as polluted regions by which the total number of patients will further increase.

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NO_x CONTROL AND PROBLEMS

The ambient air quality standard for NO_2 was first set at 0.02 ppm daily average, which is equivalent to 0.01 ppm yearly average and is the most stringent figure. Industry wanted to relax the standard because it can never be met in large cities and industrial regions even with the most stringent control on both mobile and stationary sources. The standard was revised in 1978 to the present figure with a range of 0.04 to 0.06 ppm daily average. In the regions with more than 0.06 ppm, NO_2 must be reduced to 0.06 ppm by 1985; in regions with 0.04-0.06 ppm, the present NO_2 level should not be increased. The new standard is still much more stringent than those of the United States and West Germany (Table 1).

Ambient NO_2 concentrations in several regions in large cities such as Tokyo and Osaka exceed the 0.06 ppm daily average. Some local governments have adopted more stringent NO_2 standards and want to reduce ambient NO_2 concentrations to 0.04 ppm daily average, which is equivalent to 0.02 ppm yearly average.

Recent efforts for air pollution control have been concentrated on NO_x abatement. Passenger cars manufactured since 1978 satisfy the most stringent NO_x control at 0.2 gram/kilometer. Numerous stationary sources have met emission standards based on the most advanced technology of combustion modification, which are more stringent than those in other countries (Table 3). Even with those efforts, the NO_2 concentrations are hardly lowered because of the increase in cars and in fuel consumption for stationary sources. Flue gas treatment (FGT) for NO_x removal is thus required. Even in regions with less than 0.04 ppm NO_2, most local governments want no increase of ambient NO_2 concentrations and ask industry to install FGT systems for new NO_x sources.

Table 3. Examples of NO_x Regulation and Emission for Utility Boilers (ppm)

		Regulations		
Fuel	Boiler	Central government	Local agreement	Actual emission
Gas	New	60	10	8[a]
Oil	Existing	150	100	100[b]
Oil	New	130	25	20[a]
Coal	Existing	480	170[d]	190[b]
Coal	New	400	170	160[c]

a - By combustion modification (CM) and selective catalytic reduction (SCR).
b - By CM.
c - By CM and partial SCR.
d - Desired by local government.

Among various ways of FGT, selective catalytic reduction (SCR) of NOx to N_2 by ammonia and catalyst has been by far the most advanced with the construction of about 100 commercial plants. The advantages of SCR are as follows: (a) Simplicity; (b) Applicability to boiler economizer outlet gas at 300-400^0C; (c) Reliability, which enables unattended operation; (d) Lack of a by-product disposal problem; (e) Attainment of 80 to 90% removal efficiency. The cost of SCR has been significantly reduced by recent improvements and is now about one-fifth of that of FGD for oil-fired boilers and one-third for coal-fired boilers. SCR can be applied upstream of FGD without adverse effect on FGD.

The yearly production of the SCR plants was nearly 10 billion yen in 1975. The plants were mainly for industrial boilers and steel plants. The production decreased in 1976 and started to increase in 1979 when application to utility boilers started (Figure 1).

Although ambient NO_2 concentrations exceed the standard in several regions, NO_2 may not be the direct cause of the increase of the designated air pollution patients; the concentrations are well below the U.S. standard. Photochemical smog has decreased since 1975 with the decrease of hydrocarbon emissions. Particulates emissions from stationary sources have also been reduced considerably. It is questionable whether air pollution patients are really increasing and what may be the most important air pollutant at present.

SULFATE CONCENTRATIONS

Figure 3 shows the change of yearly average concentrations of air pollutants in the five most polluted cities---Tokyo, Osaka, Kawasaki, Amagasaki, and Kitakyushu. Sulfate (sulfuric acid and its compounds) increased between 1968 and 1970, decreased remarkably between 1970 and 1973, and has since increased slightly, while SO_2 has continued to decrease since 1968. The reason for such changes in sulfate concentrations must be studied because sulfate may be more hazardous than SO_2.

The author presumes that the increase of sulfate between 1968 and 1970 may be due to the rapid increase of heavy oil consumption replacing coal as shown in Figure 4. Although flue gases from heavy oil and coal contain both SO_2 and SO_3, the SO_3/SO_2 ratio is about 3/100 for the oil and 1/100 for coal. SO_3 combines with moisture on cooling and forms mists of concentrated sulfuric acid. Moreover, heavy oil contains an appreciable amount of vanadium which is emitted in fine particulates with flue gas and catalyzes the conversion of SO_2 to sulfate in the atmosphere. As shown in Figure 3, vanadium concentration in ambient air also increased between 1968 and 1970.

Similar phenomena occurred in the U.S. between 1963 and 1969. SO_2 decreased in many regions, but sulfate did not decrease significantly and even increased in some of the regions (1); increase of vanadium was also observed (Figure 5). The author presumes that these changes may also be caused at least in part by the increased use of low-sulfur oil replacing coal during this period.

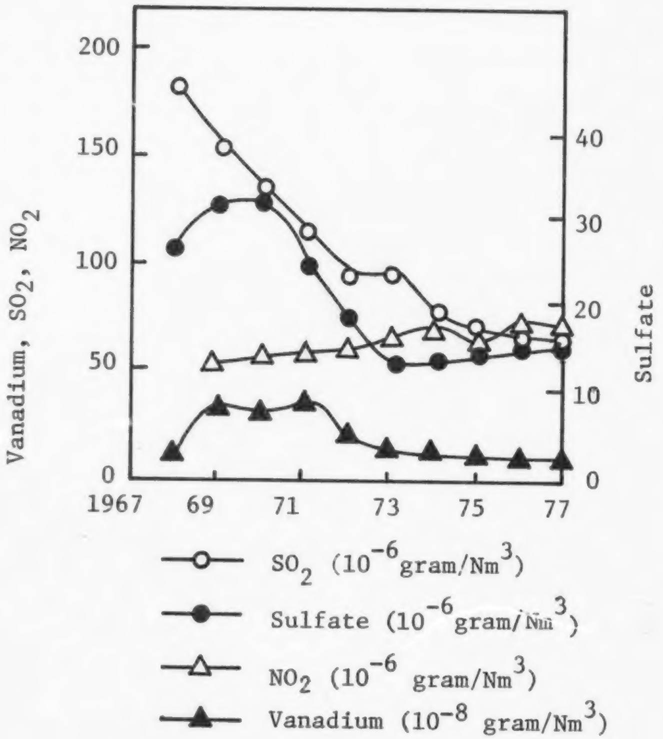

Figure 3 Yearly average concentrations of pollutants, average in 5 major cities.

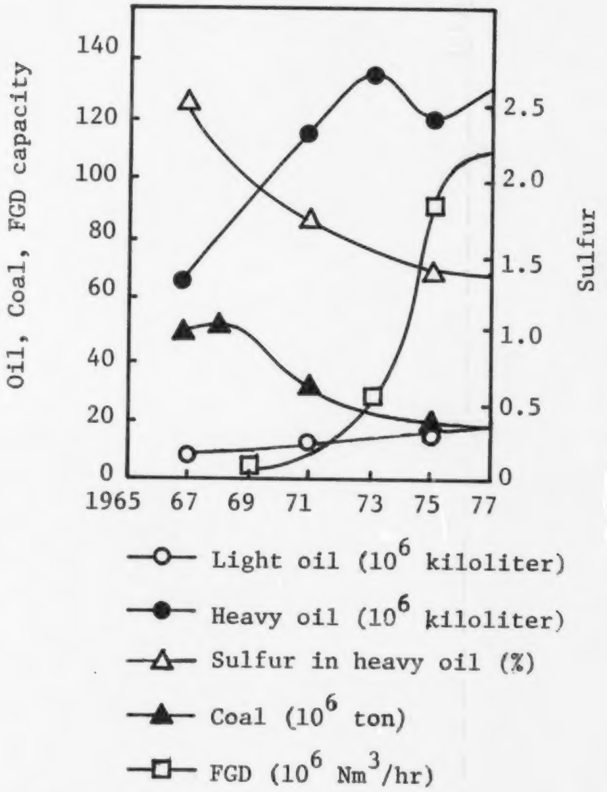

Figure 4 Fuel consumption, sulfur in heavy oil and FGD capacity in Japan

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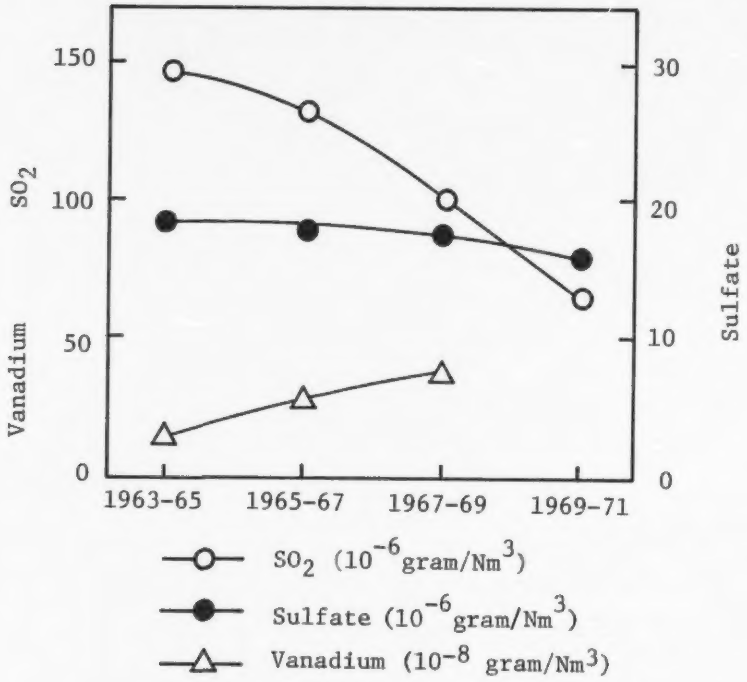

Figure 5 Change of pollutant concentrations in East Coast of U.S.A.

In Japan, both sulfate and vanadium decreased between 1970 and 1973. The decrease may be due to the following: (a) Development of FGD which removes about 90% of SO_2 together with about 70% of particulates including vanadium and also about 50% of sulfate; (b) Increase in use of electrostatic precipitators (ESP) for oil-fired boilers to remove particulates including vanadium; (c) Ammonia injection to oil-fired boiler flue gas to remove sulfuric acid mist coverted to ammonium sulfate by ESP.

Since 1973, SO_2 and vanadium have decreased with further development of FGD but sulfate has increased slightly. The increase in sulfate might be due to the following: (a) Increase in diesel engine cars, mainly buses and trucks, which use light oil containing about 0.4% sulfur (Figure 4); (b) Oxidation of SO_2 to sulfate in the atmosphere in the presence of moisture by the catalytic reaction of NO_2 which has increased since 1972. NO_2 as well as vanadium has been used at sulfuric acid plants to oxidize SO_2.

The recent sulfate concentration has been about 15 $\mu g/Nm^3$ and does not exceed the California air quality standard of 25 $\mu g/Nm^3$. However, the author presumes that a considerable portion of the 15 μg is due to sulfuric acid mists in diesel engine car exhausts, which may be considerably more hazardous because of the high concentration of sulfuric acid and possible direct effect on people. Analysis of the air on roads showed that mists of concentrated sulfuric acid with particle sizes ranging from 0.1 to 100 μm existed along with carbonaceous particles which also contained concentrated sulfuric acid (2). Carbon also works as catalyst to convert SO_2 to sulfuric acid. The amount of concentrated sulfuric acid mist in cities may be much higher in Japan than in the United States because of the higher sulfur content of the light oil and a large number of buses and trucks in cities. It may be necessary to reduce sulfur content of the light oil and to improve diesel engines to reduce particulates including acid mists.

Combustion gases from stationary sources also contain mists of concentrated sulfuric acid. Analysis of the condensate in a stack for an oil-fired boiler showed that the condensate was 70% concentrated sulfuric acid, indicating mist emissions of concentrated acid. The acid mists can be diluted by moisture absorption and also by air before they come into contact with people provided that the acid mists are emitted from a sufficiently high stack.

The formation of SO_3 in combustion gases can be reduced by combustion with low excess air, which also reduces NO_x formation. FGD by wet process usually removes up to about 50% of SO_3 together with about 90% of SO_2. Some dry FGD processes may remove less SO_2 but more SO_3. In Japan, a start has been made in the use of a wet electrostatic precipitator downstream of wet FGD, removing virtually all of particulates including SO_3 and sulfuric acid mists.

The relatively low SO_3 concentration in flue gas from a coal-fired boiler, as mentioned above, may be due to the absorption of SO_3 by fly ash. NO_x abatement for a coal-fired boiler by low excess air combustion may further reduce SO_3. NO_x abatement may also result in less conversion of SO_2 to sulfate in the atmosphere.

JAPANESE EXPERIENCES WITH SO$_x$ AND NO$_x$ REMOVAL TECHNOLOGY EXCHANGE

Flue Gas Desulfurization

In Japan, wet lime FGD process was originated by Japan Engineering Consulting Co. in the 1950's. This was further developed by Mitsubishi Heavy Industries (MHI) resulting in the construction of the first commerical plant in 1964 to treat tail gas of a sulfuric acid plant. At the beginning of the operation, the FGD plant underwent serious problems including scaling and corrosion, which were solved by the efforts of MHI.

By that time, FGD for combustion gases became important in Japan. The Japanese leaders of air pollution control, however, preferred dry FGD to wet FGD because dry FGD does not generally need gas reheating and wastewater treatment. Therefore, process developers, including MHI, tried to develop dry FGD processes for several years, with the guidance and assistance of the Japanese Government.

The efforts for development of dry FGD processsses were not successful, while the necessity of SO_2 abatement became urgent and FGD had a big market. Many Japanese engineering companies imported foreign FGD processes in the late 1960's and early 1970's; most of these were wet processes except the Shell process (Table 4).

All of the imported technologies, however, were at an early stage of development and had many problems still to be solved. The importers and the users of the technologies worked hard for the improvements, because aroused public opinion and stringent regulations allowed no violations. Through the efforts of importers and users for several years, most of the FGD plants started to work successfully. As a result of the improvements, all lime/limestone processes became similar to the MHI process in air oxidizing of calcium sulfite to gypsum; in circulating gypsum containing slurry for scaling prevention; in using a nearly stoichiometric amount of lime or limestone to produce a good quality of gypsum, etc.

MHI has had the largest share of the FGD market. Other FGD processes originating in Japan, such as Chiyoda, Dowa, Dureha, Sumitomo Metal, Kobe Steel, etc., have also been used at many commercial plants.

Since the demand for FGD started to decrease in 1975, the Japanese process developers became anxious to transfer their technologies mainly to the United States and West Germany (Table 4). However, so far only MHI and Mitsui Miike have succeeded in constructing commercial plants in those countries. Major reasons for the difficulties in commercial application of Japanese processes in the United States may be their high cost, which is due to the following: (a) Most of the Japanese processes were developed aiming at high removal efficiency and high reliability with relatively less consideration given to cost. (b) All of the Japanese processes recover useful byproducts and require more steps than the throw-away processes developed in the United States.

Low cost is important particularly for technology transfer to European and developing countries where regulations are not as stringent as in the

Table 4. FGD technology exchange by Japan

Absorbent	Process developer	Licensee	Commercial plants by licensee	
			Number	Capacity (MW)
$CaO/CaCO_3$	Babcock & Wilcox (USA)	Hitachi Ltd.	14	2,780
	Chemico (USA)	Mitsui Miike	4	830
	Chemico (USA)	Ishikawajima-Harima H.I.	3	1,050
	UOP (USA)	Ishikawajima-Harima H.I.	15	880
	Bahco (Sweden)	Tsukishima	1	20
Na_2SO_3	Wellman-Lord (USA)	Mitsubishi Kakoki	12	1,510
	Wellman-Lord (USA)	Sumitomo Chemical Engineering	6	430
CuO	Shell (Holland)	Japan Shell Technology	1	40
MgO	Chemico (USA)	Mitsui Miike	1	170
	Grillo (West Germany)	Mitsui Engineering	–[a]	
$CaO/CaCO_3$	Mitsubishi H.I.	Thyssen (West Germany)	3	1,110
		Mitsubishi International (USA)	2	1,000
		Badger (USA)	–[b]	
	Mitsui Miike	Chemico (USA) – Steinmuller (West Germany)	3	1,240
$CaO, CaCl_2$	Kobe Steel	Uhde (West Germany)	–[b]	
CH_3COONa	Kureha Chemical	Lurgi (West Germany)	–[b]	
$A\ell_2(SO_4)_3$	Dowa Mining	UOP (USA)	–[b]	

[a] None

[b] Under negotiation

United States and Japan. On the other hand, not many countries have sufficient land space for disposal of throw-away FGD byproducts. Low cost and reliable FGD technology with a moderate removal efficiency and useful byproducts may be suitable for wide application in many countries.

Flue Gas Treatment for NO_x Removal

Since the ambient NO_2 standard was set at 0.02 ppm daily average in 1973, many companies enthusiastically tried to develop NO_x removal processes, including simultaneous NO_x and SO_x removal processes, because over 1 trillion yen (about 5 billion $ U.S.) was expected to be invested for NO_x removal plants by 1980. Over 50 pilot plants for NO_x removal and simultaneous NO_x-SO_x removal were operative, resulting in the construction of about 20 small commercial plants by 1976. Those plants, however, required high investment and operating costs and, moreover, had operational problems. The economic depression since 1975 has made the large-scale application of those processes even more difficult.

Tonen Technology and Mitsubishi Chemical introduced Exxon's Thermal DeNOX process which may be the simplest way of NO_x removal. Mitsubishi Heavy Industries (MHI), together with Mitsubishi Chemical, constructed a full-scale Thermal $DeNO_x$ unit for a 375 MW oil-fired utility boiler, whereas Tonen Technology constructed several units for industrial boilers and furnaces. Besides the high cost, the process also did not seem promising because of the low NO_x removal efficiency of 30 to 50%, with leakage of a considerable amount of ammonia.

The expected big boom of the NO_x control industry disappeared in 1978 when the ambient NO_2 standard was amended. Most of the NO_x and simultaneous removal processes were given up. Only SCR has been remarkably improved and proved the feasibility of the large-scale application for a moderate cost.

Kurabo started to cooperate with TRW, Inc. to transfer SCR technology to the United States. Hitachi Zosen transferred the technology to a few U.S. firms and conducted pilot plant tests funded by U.S. EPA. Kawasaki Heavy Industries has been constructing a pilot plant for EPRI Southern California Edison. MHI, Hitachi Ltd., and Ishikawajima-Harima Heavy Industries, three of the largest constructors of boilers and SCR plants, are also to transfer the technologies to U.S. firms. Motsui Toatsu Chemical is to construct SCR units to treat waste gas from fertilizer plants in the USSR.

Among simultaneous SO_x and NO_x removal processes, the electron beam process developed by Ebara Corporation jointly with the Japan Atomic Energy Research Institute is innovative in nature in applying electron beam to flue gas to which a stoichiometric amount of ammonia was added and by converting over 80% of SO_x and NO_x to ammonium sulfate and nitrate, useful for the manufacture of fertilizer. Ebara also may cooperate with a U.S. firm for further development.

NATURE OF ENVIRONMENTAL CONTROL TECHNOLOGY AND ITS TRANSFER

In Japan, the air pollution control industry grew rapidly and has already started to decline, while the water pollution control industry is still growing, and the waste control industry has started to grow (Figure 6). Although the FGD market in the United States is several times larger than in Japan, it may be saturated in future and the technology transfer may become more important for continuing growth of the U.S. air pollution control industry.

Transfer of pollution control technology may be more difficult than that of production technology which usually has problems due to the difference in properties of raw materials, construction materials, byproduct disposal, and the quality of operators, etc. Among control technology, in a broad sense, improved production technology such as double contact sulfuric acid production process for SO_2 abatement may be accepted by users without many difficulties. Often technologies such as FGD to remove generated pollutants are not accepted willingly, because they require considerable investment and operating cost without short-run returns.

Where there is neither aroused public opinion nor governmental enforcement, users may well prefer least-cost removal technologies even though these may not work satisfactorily. Conversely, where regulations are quite stringent, as in Japan, highly efficient and sophisticated technologies may be developed which may be too costly to be adopted in other countries. Appropriate regulations with suitable guidance by the government agencies to technology developers and users are favored for the development and transfer of good control technologies.

Another point which should be considered concerning the air pollution control technology transfer is that the most important pollutant and the best control method may differ from country to country. Although it is necessary to maintain primary pollutants such as SO_2, NO_x, and hydrocarbons below certain levels, the secondary pollutants such as sulfate and photochemical oxidants formed from the primary pollutants may be more hazardous, and the manner of formation of the secondary pollutants may vary significantly in different countries due to differences in meteorological conditions. For example, SO_2 may be converted to sulfate more rapidly in Japan than in most parts of the United States and Europe because of Japan's higher humidity; whereas photochemical oxidants may form more readily in Los Angeles and Tokyo than in Europe because of the stronger sunlight. Such differences should be studied in selecting the most suitable control technology for each country.

Generally speaking, though, innovations in environmental pollution control technology may not be as remarkable as those in space and electronics technologies. This is mainly because most of the plant cost is in large simple facilities such as tanks, reactors and conveyers for treating large amounts of gas, water, wastes, etc. and partly because low cost is generally preferred to high quality. Still, innovative technologies are expected to increase, particularly in relation to the fundamental studies on the real pollutants and their formation mechanisms and control methods, areas in which the United States has been making great efforts from a global viewpoint.

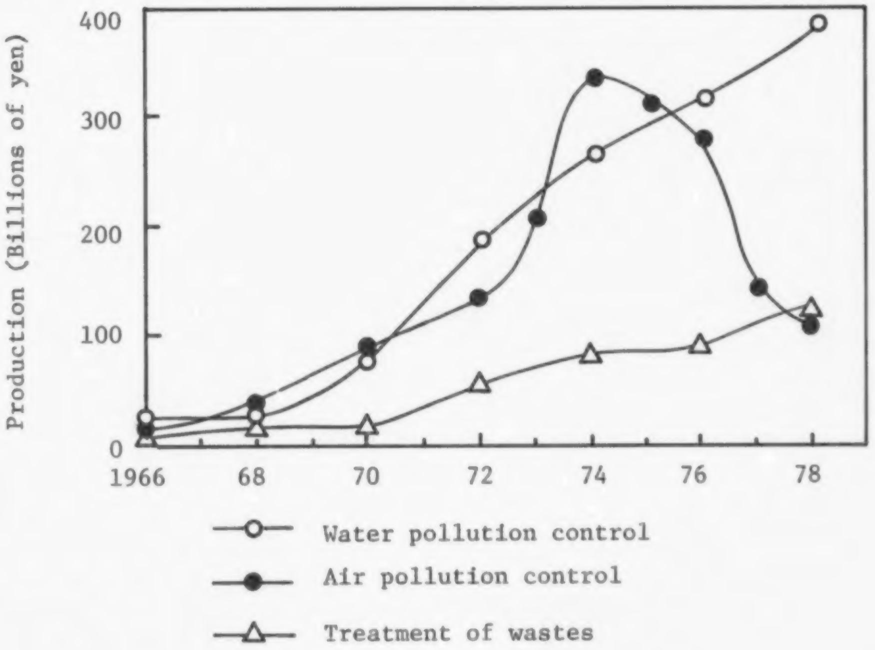

Figure 6 Yearly production of environmental control facilities

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FOREIGN TECHNOLOGY EXCHANGE

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Foreign technology exchange is induced by suitable incentives and objectives. After weighing the problems and barriers to obtaining needed technology, the seeker of such technology next looks to the available sources for this technology.

But before this process begins, the purpose of any new investment--be it for marketing innovative technologies, research and development, or for bankrolling new venture projects--is the realization of a return which satisfies the expectations from the investment.

Note that I did not quantify that return, because for many it has to be a monetary percentage of the investment. This would be an industry objective. In fact, more than an objective, because industry has to pay for wages and materials, pay its funders--the stockholders--and pay State and Federal taxes that go to serve a whole new set of objectives. If industry cannot meet all of these monetary requirements over the long term, then the investment isn't made; or, if made and not producing, it is discontinued or reorganized to achieve the required end result.

But looking at Joe Citizen, or at State and Federal Government, the return on that investment does not have to be monetary. Satisfaction can be achieved from the realization of cleaner air, cleaner water, and less noise. In these instances, the monies for these achievements come from industries' and Joe Citizen's taxes. Additionally, much of these taxes are used to set up governmental regulatory and enforcement agencies to require polluters to meet regulatory objectives. This, again, requires more investment by industry and, again, a satisfactory monetary return on that investment is needed. As long as a market exists, as long as added costs can be passed on, the investment can be made.

This new investment for pollution control equipment, however, does not just happen automatically because of new Government mandates. Industries look at alternatives to achieve the same end results at lower cost. For instance, investment in nonpolluting basic process equipment. This could work against spending money for environmental cleanup equipment on an existing installation, which, if spent, could find itself to be a white elephant should the competitor make his investment in new basic, less polluting, competitively advantageous processes. This reality must also be considered by the pollution equipment supplier since the possibility exists that his investment in new technology may find only a limited market.

This is the dilemma and problem faced by industry--the requirement to spend money on ancillary equipment rather than investing in new and innovative basic process equipment--and the problem extends to the pollution equipment suppliers.

Given the choice either to spend money on pollution control technology, be it existing or innovative technology, or spending for new cost-effective, less polluting process equipment, which alternative would you select? Unfortunately, industry doesn't always have the luxury of making a choice. In our time, additional cleanup of existing facilities is time mandated. The pollution equipment supplier has the opportunity to supply a mandated market for which he may need or desire to acquire existing or new innovative technology.

When the Clean Air Act was being developed in the late 1960's, there were about 10 companies offering electrostatic precipitators. In those days, the total market for precipitator equipment, flange to flange, was around $40 million annually, about $4 million per company. In recent years, the flange-to-flange precipitator market has been about $170 million. There are now at least 20 companies offering precipitators, which averages out at $8.5 million per company--not much of a gain considering the timespan and inflation factors. Whereas in the late 1960's, precipitators may have enjoyed a more exclusive position for various applications, today that market has been whittled down by the acceptance of fabric filters and wet scrubbers for many of those previously exclusive precipitator applications. This brings to bear another factor to consider in spending for innovative technology--for which technology should you spend?

So what did we see in the 1970's? We saw a Government-mandated market, a growth market, a prime ingredient for new investment. Of those 10 new precipitator companies, how and in what way did they get into business? Approximately half were established through in-licensing of foreign technology. This was a two-way street: U.S. companies seeking and obtaining technology from overseas, plus some foreign companies, realizing the new potential for their product, seeking U.S. licensees, and in some cases, setting up their own U.S. subsidiaries.

The other half of those 10 new companies came into existence by companies new to the market hiring from the original group the necessary experienced personnel. Out of this growth in numbers of competitors came fierce, low-profit competition to establish position and reputation. The technologies being used had been practiced for many years; innovation, such as it was, centered more on product and component improvement and manufacturing cost reduction, rather than on innovative technological breakthroughs. The poor profit levels in the decade of the 1970's never did provide industry with the capital to luxuriate in innovative, long-term research and development (R&D). The market, while temporarily big because of the retrofit requirements of industry to meet the new regulations, could not justify the venture capital for such R&D. Faced with this reality and the fact of low profit from their products, there was, and still is, little incentive for pollution equipment suppliers to spend on breakthrough innovative R&D for air pollution control equipment.

And I would suspect the same could be said to apply also to water and noise pollution control equipment supplier companies.

But is this wrong? I think not. Why should not the financial emphasis and human genius be put into developing nonpolluting, closed-cycle processes, or biological processes such as the DNA work now going on, or for treatment and conversion of raw materials to remove polluting contributors before those raw materials are processed?

At this time we are building and will continue to build better mousetraps, but wouldn't it be more desirable to find a way to stop the reproduction of future mice? To this end, I believe, Government-funded programs should be directed.

Earlier, I told you that when a market is created, suppliers will fill it. If the market growth projections are high and coupled with prospects of a profitable return, many new suppliers will come on the scene. Many of these will seek outside technology, and some of this technology will come from foreign sources. However, in the field of pollution control, there are relatively few foreign countries that have put anywhere near the degree of emission regulations into being as has the United States. Thus, foreign companies are, in fact, generally behind us in innovative technology.

There have been and are exceptions. For instance, Europeans have been very BTU conscious for many years, and coal gasification and liquification processes have been in use there for 20 to 25 years. That is in-place technology, which is being brought into the U.S. at this time. However, for some reason, our Government agencies feel we need to spend tens of millions of dollars in new gasification pilot studies and prototype plants. There seems to be a syndrome that says, if something wasn't invented here it doesn't exist and therefore cannot be considered. You might call that reinventing the wheel.

Another example is in the field of hazardous waste disposal. We in this country have been burying our wastes because this was the most economical alternative. However, we again find that in Europe safe disposal of hazardous wastes has been of concern. This led to the development of sophisticated process systems, including incineration, to dispose of toxic and hazardous wastes. Over the years, this European technology of waste disposal has improved significantly, and consequently, as a result of the potential growth market for such equipment in the U.S., this technology is being in-licensed by U.S. companies.

But there are other considerations and problems with the bringing in of foreign technology. The importing or in-licensing of foreign technology into the U.S. is, by contrast to exporting such expertise, not fraught with bureaucratic barriers such as exist in many foreign countries. Fortunately, U.S. businessmen are relatively free to negotiate their agreements without undue interference or regulation by our Government. Some of the hurdles to overcome in bringing in foreign technology are language (translating to English) and conversion from metric to English units. This sounds simple, but can be extremely time-consuming and costly. This conversion is also prone to errors resulting from faulty translation, particularly when working through a third-party translator not skilled or knowledgeable in the technology being converted or the technical terminology. Another factor of considerable importance is one of scale-up. Much of the foreign equipment and processes have lighter service requirements than those in the U.S. Performance and costs tend to suffer when sizing and building equipment and plants to meet the capacity requirements found in U.S. industries.

When markets change and there is demand for new products or systems, companies look at essentially four sources to acquire or develop the expertise necessary to serve the market.

1. In-licensing - either domestic or foreign technology
2. Internal development, inhouse or contracted
3. Joint venturing
4. Acquisition

Today our interests are with the in-licensing of innovative technology or formation of a joint venture with a partner having the desired expertise. Again, a cost study is made to decide by which means maximum return on the investment can be projected.

Once our mode of market entry has been identified, we turn to seeking out expert sources. This search can take many routes. To name a few:

- Advertising our needs through the Deparment of Commerce's Trade Administration Program that publicizes these needs in U.S. - published journals issued by our overseas embassies.

- Searching computer banks specializing in know-how availabilities such as Control Data, General Electric, Dvorkovitz & Associates.

- Retention of licensing/technology brokers who will seek out internationally those having what we seek. Brokers can be found in such organizations as the Licensing Executives Society (LES).

- Contacting trade associations of equipment suppliers who specialize in the technology we seek, such as Industrial Gas Cleaning Institute or Water and Wastewater Equipment Manufacturers Association.

- Writing to commercial industrial attachés of foreign embassies describing our wants.

- Making contacts with foreign governmental industrial development bureaus.

- Contacting foreign-located American Chambers of Commerce.

In summary, my message is this: If there is a market, industry will serve it either through the application of known technology or by the development of innovative technology, always conditioned by the reality of realizing a fair and timely return on the investments required to satisfy those markets. We must also remember that Government mandates can and often do change, and that the buying industry also has alternatives it can turn to--either of which would be counterproductive to your investment decision.

INTERNATIONAL TECHNOLOGY TRANSFER IN THE POLLUTION CONTROL EQUIPMENT INDUSTRY

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INTRODUCTION

EPA is concerned that U.S. environmental goals be met in a timely and cost-effective manner and that regulations encourage rather than stifle innovation. EPA is seeking to encourage a new generation of pollution control equipment through, for example, the increased use of the innovation waiver provisions of the Clean Air Act. Furthermore, the President of the United States has recently launched a program of coordination of Federal Government information on foreign technological and scientific advances. These factors have combined to result in extensive EPA interest in encouraging innovation. This paper presents the results of the study that examines international technology transfer as one particular means of increasing innovation in the industry. (The full results are reported in "International Technology Transfer in the Pollution Control Industry," EPA Contract #68-02-3200.)

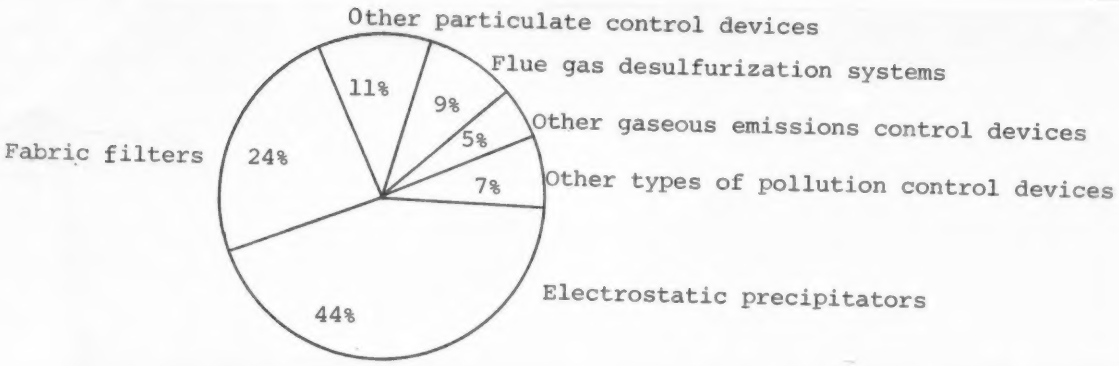
EPA's interest in international environmental R&D and technology stems from the fact that environmental issues have a strong international dimension. The same or similar pollution control problem is often of concern in more than one country, e.g., NO_x emission, wastewater treatment; and some cross-border problems result from one country's industry affecting another's environment, e.g., acid rain. International technology transfer can be a stimulus both to innovation in the pollution control industry and to improving the environment in all countries. Innovation in other countries can lead to cost-effective means of addressing environmental problems in the United States and international technology transfer (by providing a larger market for innovations in any country) can increase the economic attractiveness of R&D in the environmental control area.

NATURE OF THE POLLUTION CONTROL INDUSTRY

The air pollution control equipment industry produces particulate and gaseous emission control devices and instrumentation for air pollution control. In 1978, $628 million of these products were shipped. Particulate emission control devices accounted for 79 percent of shipments by dollar value, while gaseous emission control devices accounted for 14 percent. These statistics are summarized in Figure 1.

The air pollution control equipment industry is fairly well diversified with over five hundred domestic manufacturers listed by the Air Pollution Control Association. Some product areas, such as electrostatic precipitators, display a much greater industry concentration.

The utility companies purchased 47 percent of total air pollution equipment sales while industry purchased 53 percent, of which exports were 8 percent. Table 1 details this further. Canada was the major destination of the exports



Fabric Filters and dry scrubbers undergoing innovative technology development

Gaseous emissions control devices, especially flue gas desulfurization systems, have greatest export growth potential

Shipments of other types of pollution control devices have increased most rapidly

Figure 1. Industrial Air Pollution Control Equipment
(1978 Shipments = $627.9 Million).

Table 1. Air Pollution Control Equipment.

Customers/Markets[a]

- Utilities - Steam Electric Power Plants Purchased 47% of Total Equipment Sales
- Industrial - Industrial Customers Purchased 53% of Total Sales
  - Iron and Steel Mills (6.3%)
  - Chemical and Fertilizer Industries (6.6%)
  - Pulp and Papermills (4.7%)
  - Steam Industrial Power Plants (6.4%)
- Exports - 8% of Total Shipments ($50 Million)
  - Canada is Leading Market (28% of Exports)
  - United Kingdom, Japan, Venezuela, Belgium, the Netherlands, Argentina, and Saudi Arabia are Other Major Markets Markets

[a] Based on 1978 data.

and purchased 28 percent of the total. Mexico, Saudi Arabia, Venezuela, West Germany, the United Kingdom, Japan, the Netherlands, Belgium, and Argentina are also major markets.

Fabric filters and dry scrubbers are currently undergoing innovation technology development. Gaseous emission control devices, especially flue gas desulfurization systems, seem to have the greatest export growth potential, while shipments of other types of pollution control devices, such as instrumentation, have increased most rapidly although they are the smallest segment of the market.

The water pollution control equipment industry produces sludge digestion and disposal equipment, metering and control technology, aeration and sedimentation equipment, pumps, ion exchangers and other products. Eight specific product categories accounted for 73 percent of the 1977 shipments of treatment equipment of $932 million dollars, with the breakdown shown in Figure 2. In 1977, municipalities accounted for 54 percent of total water treatment equipment sales and industry purchased 46 percent,of which almost 8 percent were exports. Saudia Arabia, Canada and Mexico are the largest export markets.

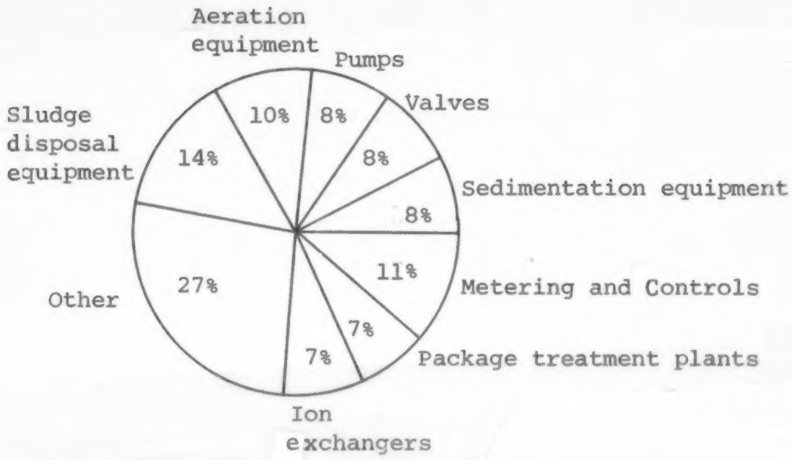
Almost all equipment categories have applications in both water supply and wastewater treatment needs for municipal and industrial facilities. Currently, U.S. instrumentation technology, included in the general category of meters and controls, and advanced wastewater treatment systems (predominantly Western Europe) are undergoing the most significant innovation.

This industry is highly fragmented; over 600 firms are involved in marketing equipment while146 manufacturing firms, owning 180 plants, accounted for 80 percent of industry sales. Most plants are very small as indicated in Table 2. In 1977, 33 percent of the establishments produced less than one million dollars.

There has been some continued rise in the sales of wastewater treatment equipment, for example, aerators and sludge-digestion equipment. United States technology for instrumentation and basic wastewater treatment (i.e., primary and secondary treatment) is felt to be superior to foreign technology according to our survey. This would indicate good export potential for these product lines. More technology development for advanced wastewater treatment is being done overseas. These are areas where there is good import or licensing potential.

What countries are likely markets for international technology transfer? The cumulative export volume in pollution control equipment for 1977 through 1980 is shown in Figure 3. It shows increasing exports in both air and water equipment categories, with water treatment equipment exports approximately double those for air. Import volume during this period was small by comparison.

For 1979, the leading air and water pollution control export markets are shown in Figure 4, and the sales data for the years 1977 through 1980 are shown in Tables 3 and 4. Developed countries (Canada, Western Europe, Japan, and Australia) account for over 40 percent of both air and water



Instrumentation and Advanced Wastewater Treatment Undergoing Innovation

American Technology for Instrumentation and Basic Wastewater Treatment Equipment (Primary and Secondary Treatment) felt to be superior to foreign technology - good export product areas

More of Technology Development for Advanced Wastewater Treatment is being done overseas - good product license areas

Figure 2. Industrial and Municipal Water and Wastewater Treatment Equipment (1977 Shipments = $931.6 Million).

Table 2. Water Pollution Control Equipment.

The Industry

- A Highly Fragmented Industry
- Over 600 Firms Involved in Marketing Equipment
- 146 Manufacturing Firms (180 Plants) Accounted for 80% of Industry Sales
- Many Plants are very small

Under $0.5M		$0.5M - $.997 M		$1.0 - $5.07 M		Over $5.07 M	
No.	Value[a]	No.	Value	No.	Value	No.	Value
39	$7.5M	22	$15.57M	69	$170.0M	50	$627.9 M

In 1977, 33% of Establishments Produced Shipments of Less Than One Million Dollars

[a] Value of shipments reported in 1977 dollars.

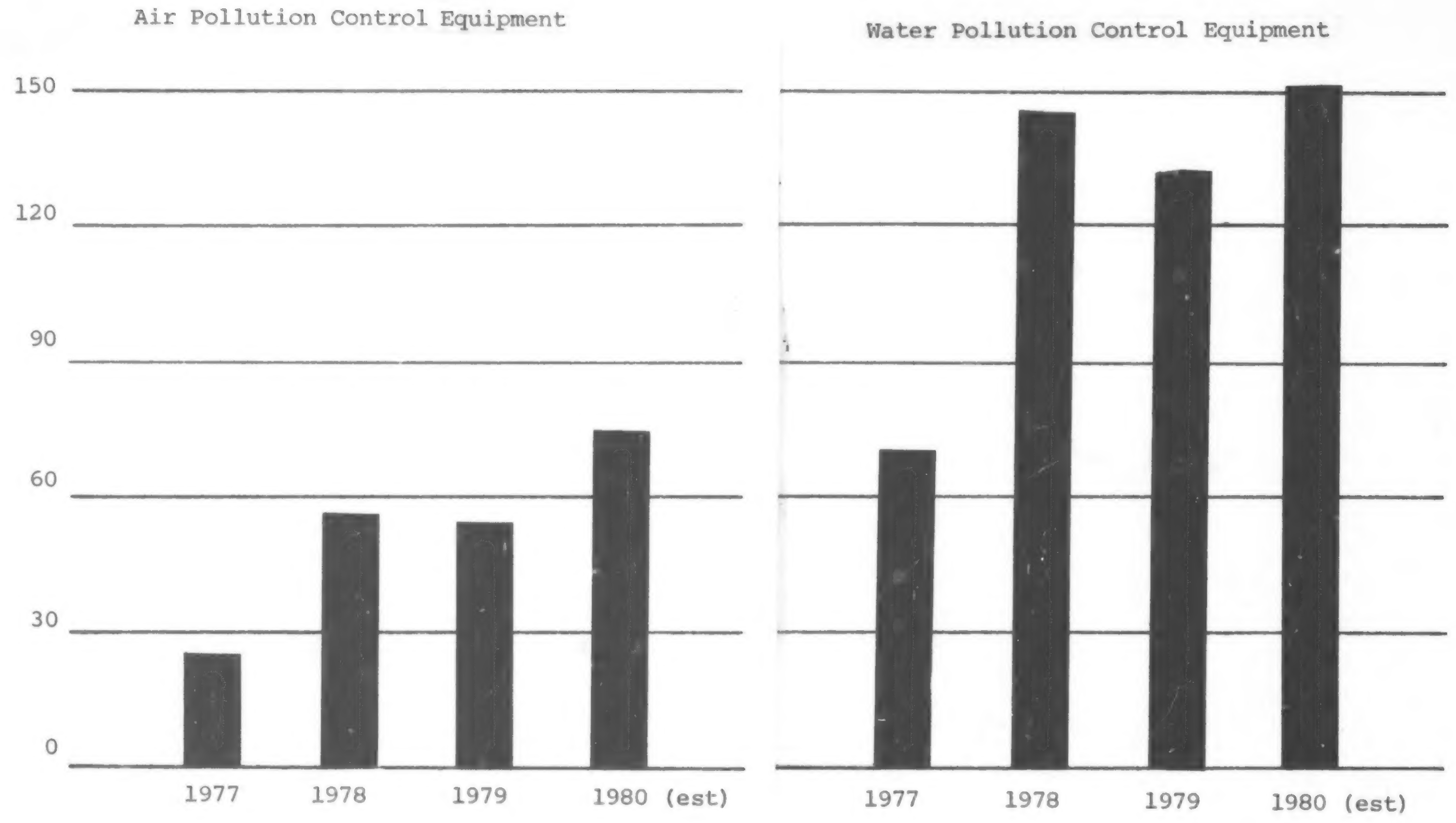
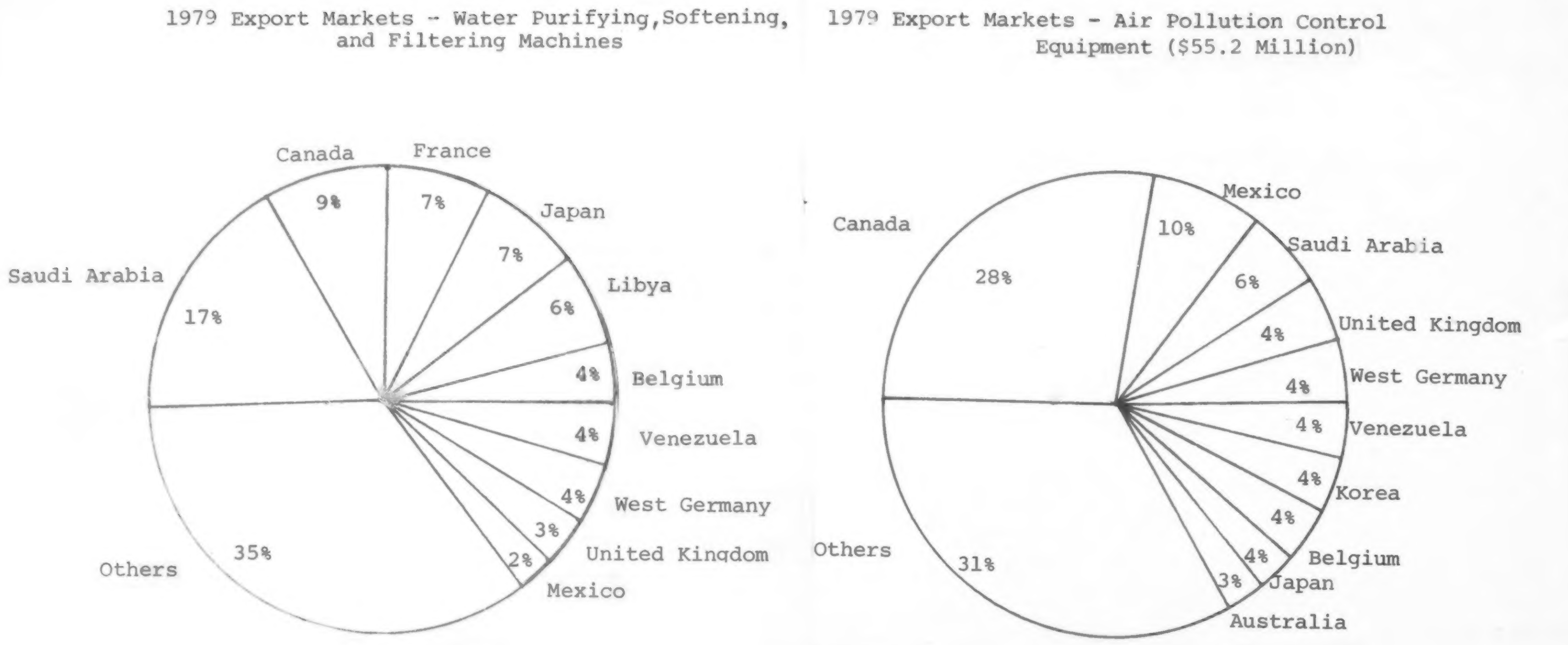


Figure 3. Export Volume 1977 -1980. ($ millions)


1979 Export Markets - Water Purifying,Softening, and Filtering Machines

1979 Export Markets - Air Pollution Control Equipment ($55.2 Million)

Figure 4. Export Markets

Table 3: Export Trends: Air Pollution Control Equipment ($000).

	1977	1978	1979	1980[a]
Canada	6,558	13,860	15,238	13,900
Mexico	233	1,732	5,676	17,187
France	559	1,056	676	1,198
West Germany	787	2,346	2,425	2,434
United Kingdom	580	2,133	2,455	2,681
Netherlands	447	2,174	1,003	2,689
Belgium	284	2,503	1,949	1,362
Sweden	139	600	649	1,166
Japan	325	2,922	1,485	2,064
Australia	241	1,143	1,489	994
South Africa	251	1,395	722	1,391
Brazil	1,576	294	593	-
Argentina	1,959	2,979	440	637
Saudi Arabia	89	5,331	3,117	5,000
Venezuela	921	3,063	2,162	2,083
Korea	213	898	2,150	2,053
Taiwan	251	748	619	1,517
Egypt	-	731	1,383	1,015
Yugoslavia	749	1,375	582	553
Pakistan	921	74	74	37
Morocco	1,528	-	1	16
Indonesia	1,735	95	276	628
Totals	24,916	56,087	55,191	73,528

[a] Estimates based on first six months sales data.

Table 4: Export Trends: Water and Wastewater Treatment Equipment ($000).

	1977	1978	1979	1980[a]
Canada	8,289	11,963	11,530	13,202
Mexico	583	2,151	3,350	11,705
France	4,346	11,195	9,629	7,160
West Germany	3,023	4,414	5,402	5,026
Belgium	5,301	5,259	5,765	4,550
United Kingdom	1,676	5,490	4,239	6,140
Netherlands	539	1,130	695	2,214
Sweden	940	1,432	996	718
Italy	1,090	2,701	2,471	3,170
Spain	565	1,288	1,199	2,190
Japan	3,574	7,979	9,375	8,691
Australia	2,552	3,463	2,890	3,037
Saudi Arabia	8,225	34,883	23,018	22,795
Iran	3,994	3,749	1,231	-
Libya	3,226	5,865	8,078	9,207
Venezuela	3,948	7,649	5,561	4,973
Kuwait	965	362	1,715	1,288
Arab Embassy	820	1,245	1,686	1,474
Bahrain	208	1,444	806	1,411
Algeria	555	1,367	1,132	349
Brazil	1,361	1,225	998	665
Trinidad	342	2,004	2,539	3,333
Korea	177	1,059	2,303	2,912
Egypt	729	1,206	829	2,681
Republic of China (T)	1,112	1,542	2,710	3,598
Totals	69,623	144,837	132,525	150,677

[a] Estimate based on first six months export sales.

FORM FOR EPA CONFERENCE MANUSCRIPTS

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treatment equipment exports and remain steady purchasers by country. However, Mexico is the fastest growing country market for both air and water equipment, projected as the Number 1 and Number 3 purchaser, respectively, for 1980.

Advanced developing countries, particularly OPEC countries, Korea, Egypt, and Taiwan purchase substantial water treatment equipment (over 40 percent) and somewhat less air equipment. They represent a steadily growing export market. Lesser developed countries over the past three years have nearly doubled the number of markets for U.S. water treatment equipment, but still represent less than 10 percent of U.S. exports.

Some previously large South American customers in both air and water equipment, such as Brazil and Argentina, have declined significantly due to import restrictions. Other Latin and South American countries represent a small but relatively steady market. Some large one-time purchases of air pollution control equipment have been made by a number of less developed countries, including Indonesia, Pakistan, and Morocco. Lastly, industrial gas cleaning equipment has shown large export gains over the past two years.

Imports to the United States of pollution control equipment have been relatively small. Commerce does not track these separately. It is known that because of Buy American clauses in most of the municipal construction programs, foreign technology is often licensed to United States manufacturers. There is significant foreign competition in the electrostatic precipitator market and recently in advanced secondary and tertiary wastewater treatment systems as well.

THE PROCESS OF INTERNATIONAL TECHNOLOGY TRANSFER

Technology transfer can take the forms of direct sales of equipment, licensing the manufacture of a technology to a foreign firm, and adaptation of a foreign technology concept to domestic use. The transfer of innovative foreign technologies to the United States is a promising means of meeting United States environmental goals and reducing R&D costs. The transfer of innovative United States technologies to other countries is a promising means of boosting rates of return on innovation and aiding the United States balance of payments.

In deciding whether to develop a new technology itself or look for transfer opportunities, every company must evaluate the usual following economic criteria: the R&D capability of the firm; the estimated development costs; the size of the market for the technology; the licensing fees or royalties; manufacturing costs; and competition. In addition, for exports the firm must take into consideration foreign competition, transportation costs, tariffs, foreign business practices, duties, exchange rates and potential size of foreign markets.

The costs of developing information on the existence of innovative foreign technologies or about the size and nature of foreign markets can be a significant impediment to technology transfer. Few firms have the staff or capability to deal with numerous foreign regulations, tax policy and permitting systems, yet many are also unaware of the range of private and public marketing services available. Hence, we find that much transfer of relevant technology and market information is by word of mouth, via personal contact with suppliers, friends, etc., rather than by an exhaustive search by an individual firm.

There are many participants in the technology transfer process. These key actors can be classified into four groups, not necessarily mutually exclusive:

- Innovators who develop new technologies;
- Intermediaries who assist the transfer process by support services;
- End users who require new or better control technology;
- Regulators who create standards, regulate international trade, control tax laws, etc.

Innovators develop new products and processes. Innovators include existing manufacturers of pollution control equipment; other industrial manufacturers with applicable experience or background (e.g., developed in chemical, mining, or computer industries); independent entrepreneurs, for example, using experience gained in industry; university, private, and Government laboratories; and the Federal Government, for example, in directly funded Government R&D or bilateral agreements with other countries.

Intermediaries are often involved in the actual transfer of the technology, from evaluating technologies available for licensing to negotiating a sale or licensing agreement for foreign technologies. Intermediaries include equipment distributors with contracts to market a foreign manufacturer's product (usually on an exclusive basis), market research and broker companies, and consulting firms which may evaluate licensing opportunities, negotiate licensing agreements or joint ventures, or research opportunities for the acquisition of foreign companies.

Regulators create pollutant standards, regulate international trade, encourage exports, regulate patent law, etc. They also are responsible for the development and enforcement of tax laws which can be powerful incentives or disincentives to industrial R&D and international commerce in general.

End users require products that enable them to meet standards cost effectively. End users in the United States and other countries with high pollution standards demand more effective or less expensive technology, creating a market for innovative processes or products. End users in countries with less demanding standards augment the market for the best established technologies.

STIMULI FOR TECHNOLOGY TRANSFER

Informal channels of discussion form one of the major stimuli to innovation. Forty-eight percent of successful innovators in a 1973 study cited informal inhouse discussion as the most valuable channel. Fourteen percent cited informal discussion with colleagues in other firms. Other information channels include professional meetings, journals and books (both professional and nonprofessional), academic studies, and inhouse conferences.

These channels are increasingly supplemented by professional organizations specializing in technology search and evaluation services. For example, Dr. Dvorkovitz and Associates, Control Data's Technotec, Technology Catalysts, Inc., the National Technical Information Service for United States Government technology, and many small technology transfer service companies and newsletters are now very active in this area.

Many companies rely only on the communications of normal business networks, conferences, and publications for information on technology transfer possibilities. Companies are unaware of existing export and innovation assistance programs. In particular, small companies, which account for much of the technical innovation, often lack the financial and staff resources to utilize the services of professional organizations or to access Government assistance programs. In general, small companies tend to be unfamiliar with the procedures involved in international trade.

There are a number of Federal efforts directed at increasing technical innovation in industry as a whole and improving exports:

A. The National Science Foundation's Small Business Innovation Research funding program.

B. The President's Industrial Innovation Initiatives affecting the National Technical Information Service and the Departments of Commerce, State and the EPA.

C. The Office of Technology Assessment study of the effect of environment, health,and safety regulation on innovation.

D. The House Task Force on Industrial Innovation, which is consolidating work on tax policy and financial incentives, patent laws, administration, trade relations, and assistance to small high-technology firms.

E. The Commerce Department's export marketing assistance program.

F. The Small Business Administration's special loan program for exporting companies.

G. The Economic Development Administration's funding for exports.

H. Senate Bill 2718 to remove antitrust and financing barriers to the creation of United States export trading companies.

I. Legislation to establish uniform patent policy, allow Federal contractors to retain patent titles to inventions, and reform the administration of patents.

EPA POLICY INITIATIVES

EPA has begun to explore ways to stimulate technological innovation in the pollution control industry. It is seeking to encourage a new generation of pollution control technology, for example, through the increased use of innovation waiver provisions of the Clean Air Act. The Agency is also giving increased attention to process modifications as a promising alternative to end-of-line controls.

Some of the leading activities under consideration include:

- Surveys of foreign government environmental regulations, enforcement policy and the directions of future pollution control.

An EPA initiative to develop and provide this information on a periodic basis would fill a large information need for firms in the pollution control industry. It would allow companies to match their products or their technology R&D programs to the needs of foreign markets for pollution control technology both present and future. The information could be assembled in conjunction with industry associations, for example, in order that a large number of companies would have easy access to it.

- Surveys of foreign pollution control technology and R&D efforts.

While the large companies are aware of technology developments in some countries, there does not seem to be any widespread understanding of the status of foreign R&D among U.S. companies. Periodic surveys of foreign technology would provide the basis for a systematic assessment of the competition in technology innovation as well as of foreign product licensing opportunities.

- Cooperation with the Department of Commerce and other agencies to provide technical and, in some cases, financial assistance to the United States companies to support exports.

A number of well-organized services provided by the Federal Government currently see little use, such as Commerce's export marketing assistance services and the Small Buisness Administration's loan program for exporting companies. EPA assistance in the pollution control industry may be able to open new export potential.

- The establishment of funding vehicles to support critical R&D areas in pollution control technology.

Although Federal policy has been to maintain a separation from industry R&D, direct governmental R&D support has achieved significant success in both technology innovation and export marketing in France, West Germany, and other countries. Consideration of R&D support targeted to particularly weak areas of the United States pollution control technology is warranted.

- Seek to persuade foreign governments to ease strict licensing regulations and import barriers.

Import restrictions in numerous countries prevent the United States companies from directly selling pollution control equipment. Licensing products manufacture to in-country firms is the chief alternative to direct sales, but increasingly involves regulatory difficulties and generally lower revenues. Relaxed regulations would enhance free trade and help boost the United States industry's competitive position in numerous countries.

VENTURE CAPITAL FOR INNOVATIVE TECHNOLOGY FOR HAZARDOUS WASTE DISPOSAL: AN INVESTMENT FIRM'S PERSPECTIVE

Arch P. Pettit, Chairman & Chief Executive Officer
Waste Technologies, Inc.

The title I have just recited suggests certain notions that I should immediately dispel before continuing further.

First, I am not an investment banker. Although the investment banking firm of Stephens Inc. in Little Rock, Arkansas is a substantial stockholder of Waste Technologies, Inc., the corporation of which I am Chairman of the Board and Chief Executive, my comments are my own insights into the investment banking community.

Second, while the title speaks of innovative technology for hazardous waste disposal, my comments are directed toward a specific technology that has been in use for more than 30 years--namely, hazardous waste disposal through rotary kiln incineration and chemical detoxification. Because these methods are of primary interest to Waste Technologies, Inc., I am more knowledgeable of their financial ramifications than I am of those of other waste disposal methods. Certain illustrations drawn from incineration and detoxification methods are undoubtedly applicable to other hazardous waste disposal technologies. However, I shall not attempt to address those parallels.

Third, the title infers that there might exist some unique, magical breakthrough means of financing hazardous waste disposal facilities that distinguishes it from other types of project financing. This is not the case. Financing of industrial waste facilities is not appreciably different from, nor more difficult than, financing of other industrial projects. The same kinds of questions need to be asked and favorably answered.

Fourth, the title infers that I might personally know something about project financing in general. To be candid, I have conditioned myself to understanding financing only to the minimum degree necessary to function as the chief executive of a newly formed corporation. My chief financial officer has convinced me that I will sleep a whole lot better if I purposely try to know as little as possible. Accordingly, I would appreciate being asked only superficial questions.

With these notions clearly put to rest, I will talk first about investment banking and then about project financing.

Investment bankers are not commercial bankers. They do not make direct loans; rather, they act as intermediaries between people with excess cash and people who have a profitable use for the excess cash. Because the investment banker deals directly with both the seller of the securities--the company--and the buyer of the securities--the creditor or investor--the investment banker is in a unique position to pass on to the seller the demands of the buyer, and vice versa. The investment banker leavens this potpourri of buyer and seller demands with the realities of current marketplace conditions, knowing that he risks losing either the buyer or seller as future customers if the benefits of the deal are one-sided in comparison with other deals in the marketplace. Since it is not common practice for the investment banker to purchase the seller's securities for his own account, the personal perspective of the investment banking firm is not the controlling factor in consummating a sale of securities. Rather, it is the perspective of the ultimate creditor who buys the debt securities of the investor who buys the equity securities that must be dealt with. Furthermore, since the perspective of a particular creditor or investor--be it an individual, corporation, insurance company, trust department, or pension fund manager--is relatively unchanging, the investment banker's most important function is matching the seller with that buyer who, having a fair knowledge of the seller's business, is willing to pay the most for the securities. The important point as far as the waste disposal firm is concerned, is to satisfy the investment objectives of a specific group of creditors and investors within the constraint that the resulting cost of capital be affordable. The investment banking role is only of significance in that it identifies the specific group and communicates those investment objectives. Accordingly, henceforth I shall speak of creditor and investor perspectives, rather than investment banking perspectives.

Regardless of the particular financing structure employed, the project's managers and financiers usually ask two critical questions.

- What is the fundamental source of the project's creditworthiness?
- Is that source of credit sufficiently risk free so as to qualify for a cost of capital which the project can afford?

Even with external guarantees of capital repayment should the project fail, the ultimate source of the project's creditworthiness is the cash flow generated by the project that is available for repayment of the costs of capital. Since no rational financier would undertake to provide external guarantees for a project that was inherently unprofitable, the availability of external guarantees does not change the source of creditworthiness but merely shifts the risks of loss to different parties. The cash flow from the project is dependent on the project's ability to price its products/services at a level which covers all the project's cost of production and capital. In other words, the question is whether or not the marketplace for the products and services will sustain prices that are high enough to pay the principal, interest, capital gains, and dividends necessary for creditors and investors to temporarily forego the use of the money.

The marketplace for industrial/hazardous waste disposal through incineration has many positive and negative factors which impact the evaluation of whether or not the cash flow is sufficient to pay capital costs. On the plus side:

- Long-term environmentally sound disposal must be secured for the country's hazardous wastes. Even without Government intervention, socially responsible firms, by definition, will produce only those consumer products whose hazardous byproducts can be disposed of safely at a cost which the price of the consumer product can recover. Socially irresponsible firms will be eventually precluded from environmentally improper disposal methods for their hazardous byproducts by legislation, such as the U.S. Federal government's Resource Conservation and Recovery Act. A market for environmentally sound disposal services will exist.

- Because incineration permanently destroys the wastes' hazardous nature, incineration is the most environmentally preferred disposal method for combustible hazardous wastes. The air emissions and ash residues from the combustion can be treated and cleaned to an environmentally acceptable condition.
- Incineration can recover the energy content of the combustible wastes and recycle such energy into the economy.
- European and Japanese experience with incineration covers over 30 years of continuing success.

On the minus side:

- Incineration is among the most capital intensive of the disposal methods. Landfill and deepwell injection, for example, presently require less dollars of capital per volume of disposed waste. Although this gap in capital disposal costs may narrow with the enforcement of more stringent environmental controls on landfill and deepwell injection, some gap is likely to remain for the immediate future.
- Incineration technology is largely unproven in the United States, especially technology which accommodates wide variances in waste streams, high temperatures, long retention times, and energy recovery.
- Some local communities have evidenced resistance to the siting and operation of waste disposal facilities because of perceived environmental, health, and safety risks.
- The specter of direct Government involvement in the industry through municipal ownership and operation of waste facilities may dampen the enthusiasm of the private sector, since their capital costs will likely be higher than those of Government.

The project's managers need to translate these plus and minus market factors into dollar-denominated financial statement projects of profitability, investment, and cash flow. The management plan, besides numbers, will have to document assumptions, tasks to be accomplished, management expertise, risks, competition, and many other qualitative factors. Ultimately, the investors and creditors must reach a judgment as to whether or not the returns merit the risks in comparison to the risk/return profiles of alternative uses for their money.

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The rational creditor or investor will require a return that is commensurate with the risks inherent in the undertaking. Obviously, the greater the perceived risk, the greater the required return. Because management's responsibility to the present owners of the business is to maximize the profits accruing to such owners, management's goal is to obtain the lowest overall cost of new capital. Specifically, management seeks the lowest interest costs possible without impairing management flexibility, and the sale of stock to new owners at the highest prices possible. Achievement of these objectives requires management to minimize both business risks and capital risks where such actions do not interfere with the profit-producing character of the project.

Certain business risks, such as the capital intensity or novelty of the chosen method of waste disposal, are uncontrollable by management once the method of waste disposal has been selected. Other factors, such as the internal policies of investors and competing investment alternatives for the financial communities' moneys, although impacting the cost of capital, are outside the sphere of influence of management and are likewise uncontrollable. Management, however, can and should undertake to minimize some risks.

Management can mitigate the resistance of the local community to the siting and operation of waste disposal facilities through candid and frequent meetings with townspeople on the environmental, health and safety risks. Management can dilute the specter of direct governmental involvement by providing quality services in sufficient quantity to obviate the need for governmental intervention. Through assembling a high-caliber management team, management cannot only dampen the threat of effective competition, but also bring the project in on time, at the projected capital cost and within the envisioned margin of profitability. Lastly, management can substantially eliminate some business risk 1) by entering into long-term "take-or-pay" contracts of disposal services, 2) by purchasing sufficient insurance to protect against property loss, personal injuries, and environmental hazards, 3) by sheltering the investors' dollars with tax benefits including tax-exempt status for interest income, 4) by local, State, and Federal guarantees of debt repayment, and 5) by structuring the capital of the company to optimize the competing interests of the debt and equity holders.

The capitalization of the project should blend the various forms of debt and equity so as to gain the benefits of leverage through the lower after-tax cost of debt securities. At the same time, however, the capitalization should provide a sufficient equity cushion to give creditors the required comfort and keep debt service charges from strapping the project should start-up cash flow fall short of expectations. Conventional forms of capital are bank loans, bonds, and stock. As a practical matter, if the project cannot be financed with conventional securities, then the project cannot be financed at all.

More exotic forms of project financing are not a cure for insufficient profit margins. Some forms, such as leverage lease financing, can pass tax benefits to those high-bracket taxpayers who can gain the most economic benefit from them. Other forms can achieve off-balance sheet accounting treatment during the construction period. Yet invariably, the additional benefits gained from such exotic forms are not of such surety and substance as to make

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worthwhile a project which would otherwise fail under conventional methods. The critical questions, "What is the fundamental source of the project's creditworthiness?" and "Is that source of creditworthiness sufficiently risk-free to qualify for a cost of capital which the project can afford?" must still be answered favorably.

FEASIBILITY OF AN INDUSTRY-SPONSORED AIR POLLUTION CONTROL RESEARCH INSTITUTE

A. B. Walker, Vice-President
Planning and Development
Cottrell Environmental Systems

One of the crucial issues this country faces in the coming decade and one which everyone will have to contend with is the issue of how to have energy sufficiency and clean environment at a reasonable cost.

It is common knowledge that known fossil energy reserves lying within the United States boundaries are sufficient to meet domestic energy needs for about the next 300 years.

The critical issue is whether these reserves can be extracted and used without the process expending more energy than is produced and without destroying the environment. This is going to take innovation in breaking down institutional barriers to the extraction and transport of our energy resources, and innovation in technology to assure that this is effected in an energy-efficient and environmentally acceptable way.

Unfortunately, for environmental companies, there are many disincentives to the application of current technical resources to these problems.

These disincentives occur in the form of regulatory and business practices. These tend to increase the risk of the pollution control business without providing a compensating opportunity for increasing profits, and thus drive management toward investing their technical resources in other areas.

The pollution control business has come to be viewed by its leading participants as a high-risk business. In some cases, top management is diminishing the importance of this business to the corporation by limiting further investment or by actually getting out.

So we have a scenario of industry tending to reduce its commitment just at the time when we need a renewed commitment to provide the technical innovations required to achieve our energy and environmental goals.

If we do not reverse this trend, we run the risk of not having the technology and industrial capacity to meet the new environmental protection needs of our energy programs. This will result in constraints on our energy supply or in degradation of our environment.

How can we reverse this trend? The problem is basically one of moving the risk/reward ledger into a favorable balance. We must come up with mechanisms that will allow prudent businessmen to decide on sound business principles to continue to commit their technical resources to innovation to satisfy the energy-related environmental needs.

Business executives make such resource allocations in terms of expected return on investment, return on assets, etc. Therefore, the issue is either to reduce the investment or assets, or to increase the probability and magnitude of the return, or both.

Increasing the investment return and the certainty of that return has to do with the elimination of many institutional barriers such as prohibition of proprietary patent rights in Government-funded research and development (R&D), requirement for supplier-acceptance of consequential damages, regulatory policies that mandate new technologies while forcing premature obsolescence of others. This is an extensive subject in itself that various speakers at this conference are addressing. It is the other side of the equation I would like to address, with particular regard to control technology for air pollution.

How can the Federal Government best channel funds to the air pollution control industry in a manner that will stimulate innovation? Webster's definition of innovation is: to make changes by introducing something new; a new idea. Most people here will agree that most of the money provided by the Government in the pollution control area is going into the development and demonstration of new ideas rather than into the stimulation of the ideas themselves; and that the generation of ideas thrives best in an uninhibited environment which is investigating the more fundamental and speculative aspects of a technology.

This is precisely where the pollution control industry has not invested funds because it is too speculative an area, and yet this is precisely the one that must be stimulated. It is questionable whether Government grants and contracts to universities and contract research organizations stimulates the industry itself. Often the contrary is the case. Many a research director is demotivated by what he sees to be "reinvention of the wheel" as a result of such grants, and filled with a sense of frustration over his own inability to gain access to such funds on account of the profit-making status of his firm tendering him ineligible. Admittedly, stimulating the academic and contract research community to devote effort to satisfy the need for new air pollution control technology is well and good, but not at the expense of closing out the contribution of those from within the industry.

One approach might be Government-supported cooperative industry research. The Industrial Gas Cleaning Institute (IGCI), which is a trade organization whose members provide about 80 to 90 percent of the purchased stationary source air pollution control equipment, has been exploring the feasibility of such an approach through an ad hoc committee. This committee has recently conducted a survey of other industry organizations (selected at random as those with probable significant interest in air pollution control) to determine the existence and extent of cooperative industry research and the Federal Government's role in it. Table 1 is a summary of the essential results of that survey.

At one end, and notably for the size of their annual budgets, are the Gas Research Institute (GRI) and the Electric Power Research Institute, (EPRI). Both of these organizations are essentially publicly financed--privately managed research and development programs funded by an assessment in the rate base for either natural gas or electricity. Specific criteria for

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TABLE 1

RANDOM SAMPLE

Cooperative Industry Research

Organization	Approx. Annual Research Budget	Approx. Permanent Staff	In-House Research	Govt. Funded Research
	$ (MM)	No.	% Total	
Portland Cement Assn.	5.0	140-150	95	Yes
American Petroleum Institute	8.0	None	0	Yes
Sulfur Institute	<0.2	0	0	No
Bituminous Coal Research	5.0	30-40	100	Yes
Nat'l Council for Air & Stream Impr.	3.5-4.0	50	90	Yes
Gas Research Institute	35-50	150	0	Yes
American Boiler Mfgrs. Assn.	<0.5	2	0	Yes
Textile Research Institute	1.0	50-60	100	Yes
Electric Power Research Institute	250.0	650	5	Yes

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guidance of State regulatory commissions and the Federal Energy Regulatory Commission in approval of such assessments have been established by the Federal Power Commission. Thus the gas and electricity consumers are paying for the research and development (R&D) directly, under the rationale that such R&D will ultimately benefit the consumers in the form of lower rates, and the stockholders of the gas and electric companies will not benefit preferentially because these rates are regulated. The Gas Cleaning Institute and the Electric Power Research Institutes are essentially program management organizations who contract out almost all of the actual R&D.

At the other end of the spectrum are the Portland Cement Association, Bituminous Coal Research, Textile Research Institute, all of which are financed by contributions from member companies in the form of direct project support or through unrestricted contributions. They are essentially staffed to conduct their research inhouse. The rationale for the member company contributions lies in the conviction that there are some areas of common interest which, while too speculative or possibly too expensive to explore individually to gain more competitive advantage, if explored collectively will benefit the total industry.

The dilemma for the pollution control industry is that neither model seems to fit the situation. On the one hand the pollution control industry is not a regulated industry and thus would appear, at least superficially, to be ineligible for the regulated utility-type of financing. And on the other hand, given the present risk/reward situation, the outlook is extremely pessimistic for the pollution control industry to mount a cooperative industry research effort on its own, because the collective budget based upon what each company feels it could afford for nonproprietary research would be too small to mount any meaningful effort.

However, if the collective contribution could be leveraged by matching Government grants, a meaningful budget could result and thus provide the stimulus for the industry to move seriously toward the creation of such a collective research effort; and once there is concurrent movement on the other side of the equation, toward a better balance of risks and rewards, a pessimistic outlook might be converted into one of cautious optimism. While it may be a precarious prediction, I would venture to say that if the U.S. Environmental Protection Agency (EPA) took the initiative with such an approach, there would be a rapid and positive response from the air pollution industry.

The key word is initiative. It must come from EPA for it will not come from the industry given the present trends that have been described.

A good example of an effective external initiative is the previously described Electric Power Research Institute. EPRI has its origins in a proposal by Senator Warren Magnuson in 1971 for the formation of a Federal Electric Power Research Institute funded by a 1-percent tax on electric power use. Rather than see the evolution of the technology in the industry pass into the hands of the Federal Government, the utility industry, both public and private, moved quickly to the formation of its own collective industry research institute in 1972. Thus, an external initiative triggered an industry reaction that has resulted in the desired effect--stimulating the private

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industry sector to generate research in the public interest.

For the air pollution industry, the trigger must be an EPA initiative to offer to match, on a high-ratio basis, funds generated within IGCI from assessments of member companies for a cooperative industry research program. The likely result would be the incorporation by IGCI of an IGCI Research Institute and the organization of an administrative staff and Research Advisory Board consisting of representatives from IGCI member companies, EPA, and potentially other appropriate government agencies, to formulate and direct a cooperative research program. This institute would probably take form similar to EPRI or GRI -- a program-management entity which disburses grants on contracts to member companies and/or universities and contract research organizations.

The sources of the matching funds need to be explored further, but certainly the rationale that pollution control R&D is in the public interest is applicable and should thus be the recipient of public funds. The innovation required is an effective means of funding an unregulated industry without preferentially benefiting the stockholders of companies in that industry over the general public.

One might ask how the existence of such an air pollution control research institute as I have described changes the situation we have now. All we would have done would be to move the overall administration of the innovative efforts in air pollution control technology from the EPA to the control technology industry. And isn't that a desirable goal?

<ins>Question</ins> (John Roberts): Mr. Walker, I have been involved in research fundraising for universities for a long time, and I am under the impression that universities think that Federal grants for basic research is <ins>their</ins> money. We had the experience with the National Science Foundation's (NSF) RAM project, for example. That gives me reason to believe that if you develop an institution as you described, you are going to incur the umbrage of the university research community.

Do you have that impression, and if so, how do you think you would be able to deal with it?

<ins>Response</ins> (Alan B. Walker): I don't want to bring down the wrath of the academic community, but I think the real concern and conception is that somewhere there should be some industry input into the guidance and direction of those funds into the academic community.

Now, I know that smacks of putting all kinds of constraints on research, and what we really want to do is have unrestricted funds for exploratory research. I think the concept is to try to find some mechanism for introducing the intellectual capacity of the control technology industry itself into the process in order to avoid what we perceive as reinvention of the wheel; that is not cost-effective use of those funds.

Impact of Regulatory Policies and Industry Reactions: Case Studies

Chairman:
Frank P. Partee
President, Air Pollution Control Association
Consultant, Stevens, Inc.

Panelists:
Frank P. Sebastian
John H. Mahon, Ph.D.
Donald D. Marple
Norman E. Tadlock

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INTRODUCTORY REMARKS

Frank P. Partee, Consultant
Stevens, Inc.

I would like to welcome you to this last portion of this morning's program: The Impact of Regulatory Policies and Industry Reactions.

My name is Frank Partee. I am with Ford Motor Company and as past President of the Air Pollution Control Association, I am very pleased that our organization had the opportunity to participate in this Conference, which itself is an innovative and cooperative effort between the Air Pollution Control Association, U.S. Environmental Protection Agency (EPA), the Water Pollution Control Federation, and the Environmental Industry Council.

I hope this Conference can prove a model for future collaborative ventures to present more programs of better balance and broader environmental perspective than might result from our respective parochial viewpoints.

The impact of legislation, regulations, and regulatory policy on pollution control technology innovation is one of the most important facets of this Conference, and I think that is certainly manifested since all the previous discussions have touched on it to some degree.

Great risks are imposed on both the providers and the users of innovative pollution controls. The technology-forcing philosophy imbedded in our environmental laws, combined with mandated deadlines for compliance and massive fines for failure, have just as much potential to act as strong deterrents to innovation as to provide incentives.

One reason is that the risk in these endeavors is not equally shared -- with Government's portion at, or close to, zero. This imbalance must be addressed if we are to improve our record nationwide to search for and apply innovative control technology.

Certainly EPA has shown its sensitivity to this problem by participating in this Conference and through the thoughtful remarks of Mr. Costle yesterday morning, and I hope that many useful suggestions that will impact on regulatory policy will flow from this Conference. In fact, in retrospect I wish that we had provided, within the mechanism of this meeting, for some workshops as was done at a recent conference that had to do with innovations in the administration of air pollution controls as fostered by EPA under the general heading of what they called "control trading."

In that meeting, the private sector in particular was given the opportunity to give concrete suggestions on how these regulatory innovations could be made to work better. It is our impression that the results of those suggestions are in fact affecting EPA policy, so I will leave that suggestion with you, Dr. Reznek, and perhaps somehow we can bring that to bear.

Obviously not all governmental regulatory actions impact innovation in control technology negatively, and I would like to mention just briefly a case affecting my own company, the Ford Motor Company. This emanates from the current concern of ozone depletion in the upper atmosphere due to the release of chloralplural carbons. Among these compounds, one of the best known is Freon, or R-12, which is commonly used as the propellant in aerosol spray cans and the refrigerant in air-conditioning and cooling systems.

Under the authority of the Toxic Substances Control Act, and based upon preliminary scientific findings that ozone depletion would occur from the continued release of chloralplural carbons (CPC's) leading in turn to an increased incidence of skin cancer, EPA abolished nonessential uses of CPC's. This led to a very rapid response by manufacturers for new and innovative products, substituted propellants, or mechanical atomization in a wide variety of products from underarm deodorants to spray paint. The regulation of the more complicated air-conditioning coolant systems was reserved for a variety of reasons including confirmation of the original scientific hypothesis alleging damage to the upper ozone layer.

Meanwhile Ford immediately began and is continuing to search for substitutes to Freon for use in automobile air-conditioners. As part of this work, a close examination was made of our process in which the air-conditioner units themselves are made, and it was determined that as part of the normal production methods, the units were charged with Freon, tested for leaks, and then evacuated for shipment.

The Freon vented was lost to the atmosphere. We had instigated an innovation into this process which would not have occurred without the threat of the impending regulation to allow recycling of the Freon used for leak checks. This eliminated the emission and actually resulted in a cost saving to the company.

The particular situation is continuing, and we are now examining the use of substitute refrigerants among which is one called R-13A, or tetrafluoroethane, and this is being done in anticipation of the future total ban on production and use of Freon in the United States.

This compound performs as well as Freon; has none of its undesirable properties affecting the ozone; and would require no retooling cost to the industry, which is a very important point. There is only one catch. The material cannot be made in mass quantities at an economical cost.

Someone must now tackle the risk of a major research and development (R&D) program aimed at developing an economical production method for R-13A, and this must be done without knowing whether or not the total ban will in fact ever be imposed. So I think situations like these underscore the impact of regulatory policy on the matter that we are all concerned about, which is the introduction of innovative technology. We are fortunate in having a distinguished panel to provide a variety of viewpoints on the subject. As you see, we have represented both providers and users as well as the academic viewpoint.

MUNICIPAL CONSTRUCTION GRANTS PROGRAM AND INNOVATIVE TECHNOLOGY - PROBLEMS, BARRIERS, MARKET STABILITY

Frank P. Sebastian, Senior Vice-President
Envirotech Corporation

My topic is the Municipal Grants Program: innovative technology, problems, barriers, market stability, etc. I can identify very closely with the comments of the speakers that I have heard earlier today about many aspects of this. Our company, in 1962 to 1963, before Envirotech was formed, led a number of trade missions to Europe and to the Orient to talk about America's advanced technology. I would say we were more successful and probably had more impact in Japan than in other countries in Europe or Eastern Europe.

We can sympathize with the point that Mr. Walker made about premature obsolescence of technology and the forced technology that Frank Partee mentioned, because the subject that we talked about in the 1960's on most of these trade missions was producing drinking water from sewage.

We were using the Tahoe plant as an example at that time. I think it had the first research and development (R&D) money from the 1965 Federal program. The Tahoe plant got the first grant for a million dollars for upgrading this plant and to finish it off to make drinking water from sewage. I don't think we ever really sold anything in that plant module again because the requirements of the Clean Water Act that was enacted to make drinking water from sewage never really came to pass.

In 1969 I went to South Africa to see the only plant in the world that made and used drinking water from sewage and they had contrasting technology. They used activated granular carbon as one of the unit processes, but they didn't believe that you could regenerate carbon, so they threw it away or stacked it up in a pile like hay. And here in the United States we did not believe you could drink the water, but we knew you could regenerate carbon. So these were interesting contrasts.

I was to testify before one of the House subcommittees on estuary pollution on the invitation of our Congressman Peter McCloskey, so I brought a sample back of this water. My then eight-year-old daughter Sheila -- you have to mention the name, I understand -- carried a gallon of repurified sewage 18,000 miles from South Africa through North Africa to London and home. We arrived here one night and were in Peter McCloskey's office the next morning at 9 o'clock saying "Yes, the plant does exist. I'd like to tell about it in my testimony."

So I talked for twenty minutes, which I realize now is an unusually long time to talk to someone on Capitol Hill, and he looked over at my eight-year-old who was sitting on the sofa and said, "Well, Sheila, you're very quiet. What do you think about all this?" Sheila replied, "Well, the water tastes better before you see the plant."

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That, in short, was the impediment to that technology, and I just wasn't smart enough to realize it. But Mr. Partee has a very much greater opportunity, I think, in the automotive business than we do in the Grants Program in terms of the long lead times that exist for getting our technology into use in more than one place.

When the first crunch on fuel economy hit about six years ago, our company announced a policy: We had to move into smaller, more fuel-efficient cars. For the first time in a long time I got into a car that I couldn't quite sit up in. It was one of the first European-designed cars. And I was struck the other day to see the same body shell in the current models with a 50-percent improvement in gasoline mileage over that which I got six years ago.

They can still amortize the tooling for that design and have a 50-percent improvement in fuel economy, which is the name of the game. You hear a lot of complaints from the automotive industry, but they don't know what problems are compared to those of us who are trying to introduce new technology in these long-lead-time projects where, so frequently, economics or change in the Federal regulation overtake your technology before you really have a chance to realize your investment on it.

Some of that, I think, will be reflected in my comments this morning, but in the interest of time I will speed along here.

Following a three-and-a-half-fold growth in annual Construction Grants from FY 1972 to FY 1979, during which growth in wastewater equipment needs roughly paralleled this, there was an estimated 50-percent reduction in equipment requirements in 1979 from the previous year's requirements. This happened at a time when grants actually increased from the previous year to 3.9 billion dollars from 2.38 billion dollars.

That meant we had a reduction in equipment needs at a time when the whole grants program was increasing during the 1979-1980 period. This drastic slump in equipment needs was partially triggered by a U.S. Environmental Protection Agency (EPA) freeze on equipment-based projects versus land systems, accentuated by major business weaknesses which had accumulated in the equipment industry through the implementation of the Clean Water Act of 1972.

Despite the huge numbers, the size of the Grants Program, from the viewpoint of the equipment industry and particularly relating to innovative incentives, it must be recognized that the program had also been badly decimated by inflation. Or, as the industry's leading investment analyst put it recently at the WPCF convention, "Do you realize that in 1972 dollar terms, that is after adjustment for inflation, the $3.4 billion that is scheduled to be authorized for FY 1981 is less than $1.8 billion and is thus 64 percent less than the 5 billion dollars forecast at that time?" Who knows what portion of that will go to interceptors and to other nontreatment-related construction. "Compounding the problem," as the analyst went on, "are the lack of stability and predictability in the program; the need to stabilize the congressional authorizations; the need to restore the role of the consulting engineer's professional judgment; and allow proprietary product advantages." The additional problems that I would add to that list would be the bid qualification procedures -- the procurement regulations relative to innovative or alternative wastewater treatment systems; the unwarranted emphasis on land techniques; and progess payments, retentions, and excessive litigation.

One result of the equipment industry's economic crisis during which some five or six of the largest manufacturers have either withdrawn major project lines or drastically reduced the resources available to the Grants Program, is that the EPA has identified an enormous potential: some 6 billion dollars of equipment-oriented needs for the big cities that should fall into the 1981 to 1983 period.

Whether or not adequate resources to supply these needs will be available is largely dependent on the support given by the various sectors of the Grants Program in implementing program reforms to economic shortcomings.

Particularly relevant to this forum is the impact all of this had on R&D expenditures from 1975 to 1980, according to a survey we conducted last summer of six of the major equipment companies that participated in this survey. "All the R&D comes from the Government, doesn't it?" we asked. They looked at the staff and looked at one another and all nodded their heads. That is where innovation and new processes come from.

I was involved as one of the officers with the Wastewater Equipment Manufacturers Association at that time. We surveyed the membership and the membership of that group felt that, "All the innovation, all the new ideas came from manufacturers. It didn't come from anywhere else." As is usually the case, neither view was right. It was somewhere in the middle. But we did review the EPA manual recently on innovative and alternative technology. Then one of our long-time employees who had just retired went down that list of processes and identified what he thought the basic source of the technology had been. Had it come from consultants, Government, or industry? And 49 percent of the listed processes he identified as having come from the wastewater equipment people. I feel that is fair, so this should be a matter of concern to the current and next administrations to restore some incentives for industry to put money in R&D and have a chance to earn a profit on it.

What about solutions to these problems? They have been extensively considered by an ad hoc group of some eleven of the largest companies that are supplying equipment to this market. These recommendations have been made to the White House staff, the leaders on Capitol Hill, and the leadership of EPA. We hope something will come from this.

Specifically, in the bid qualification area, this has been, we believe, the fundamental, underlying problem in the lack of incentives for new technology because of the restraints on the professional role of the consulting engineer.

There was a time when the consulting engineer made his professional judgment, and he was really the only one in the whole hierarchy that we felt could make a judgment decision. All others were using their judgment to interpret the law or interpret a regulation but that was substantially wiped out with the full implementation of Section 20486 of the Clean Water Act.

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Fifteen months ago EPA issued a prequalification procedure that has not been widely used. As a matter of fact, it has only affected, to my knowledge, a few jobs, and this would be a first step in restoring the professional judgment role of the consultant, which would enable you, your companies, and organizations involved in R&D to try to get this new technology put into use.

In the innovative and alternative technology (I&A) area, we think that unless the sole source provisions of the Act are really utilized -- made widely known by EPA -- there would not be opportunity to sell but one of your innovative processes because the second time around the whole world will come in and underbid you.

We worked on one project in the Midwest for five years, had some new technology that was energy efficient, and it was put in with the last modification by the consulting engineer in the city. When it came time to bid again, another company who had not been on the scene before came in and underbid us by a substantial amount of money and walked away with the job.

Now, whether they will ever be able to finish the job doesn't enter the judgment decision. You cannot just turn down someone who offers a bid in this business, and that was a major factor, I might add, why we withdrew from the whole product sector. We just do not make that equipment any more.

So we think that the sole source provisions of the Act need to be far more broadly articulated by EPA and pushed so that communities know this can be done and have a chance of getting their investment back.

The emphasis on land techniques, in my view unwarranted, is another detriment to equipment-based technology and hopefully EPA will be able to broaden their perspective on that, too.

On the financial side of business, the progess payments, reduced retentions, and reduced litigation, are very important aspects that also need to be addressed, but I won't go into those in any greater detail.

If large, responsible companies are to restore interest in R&D, indeed even to continue supplying equipment for municipal wastewater treatment, prompt action must be taken to resolve the problems I have identified to complete the cleanup job that should be the compelling objective, an elimination of the concept that so effectively slowed it down.

Even during this transition period I find encouragement in Mr. Costle's open letter last May to Pollution Engineering Magazine in which he stated he was seriously concerned over the economic pressures being borne by the many segments of the pollution control industry. I hope he can effectively do something about them in these remaining months in his office.

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ISSUES THAT ADVERSELY IMPACT THE POLLUTION ABATEMENT INDUSTRY

John H. Mahon, Vice-President, Regulatory and Trade Affairs
Calgon Corporation

Calgon Corporation is a wholly owned subsidiary of Merck & Co., Inc., a major pharmaceutical manufacturer involved in three related business activities:

- Human Health
- Animal Health
- Environmental Health

Calgon's primary business is helping industry and municipalities solve problems, particularly those related to the treatment, use, and disposal of water. The first focus of this paper will be on Calgon's water treatment activities relating to the purification of drinking water. Specifically:

- Removal of precursors of trihalomethanes
- Removal of synthetic organic contaminants

The reduction of trihalomethanes may involve the use of water-soluble polymers to enhance and facilitate the removal of naturally occurring organic materials that contribute to the production of trihalomethanes upon chlorination of the water. Precursor organic materials can also be removed by adsorption on granular activated carbon. Both of these procedures have been shown to be effective in reducing the quantity of trihalomethanes produced upon chlorination of the drinking water.

Synthetic organic contaminants are best removed by passing the source water through a bed of granular activated carbon, which will adsorb and remove a wide range of soluble organic contaminants.

Calgon has been producing granular activated carbon since 1941 -- first for use in World War II gas masks and then for industrial water and food-related applications. During this time, we have developed a great deal of useful knowledge about the design of carbon treatment systems and appropriate pretesting to determine how well granular activated carbon will remove specific materials from water. Our expertise extends to the pretreatment of granular activated carbon before high temperature thermal regeneration, and the safety in handling exhausted carbon in our plants and during transportation. The objective is a safe operation to produce a high quality and reliable regenerated carbon.

Removal of Trihalomethane Precursors

From Calgon's perspective, the trihalomethane regulations promulgated by the U. S. Environmental Protection Agency (EPA) on 11/29/79 will have little impact on the use of granular activated carbon. Better preclarification with polymers, changes in chlorination level and location within the

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treatment plant, and the use of chloramines will permit the majority of municipalities to comply with the 100 ppb trihalomethane regulations without the need to use granular activated carbon. Further, these regulations will not be fully operable for municipalities with more than 10,000 customers until 11/29/83. Municipalities with fewer than 10,000 customers, which serve 50 percent of the population, are not affected.

Our attention was initially directed to the trihalomethane problem by the EPA draft proposal in 1977. Thus, it will be six years before large-sized municipalities (more than 10,000 customers), that serve 50 percent of the population, must comply. This is a long time despite EPA's sustained desire to promulgate these regulations whose content has not changed significantly over the years.

Removal of Synthetic Organic Contaminants

The EPA's desire to minimize synthetic organic contaminants in drinking water received its formal publicity with the New Orleans announcement of 11/8/74. The early EPA proposals concentrated solely on surface water contaminants and proposed the use of deep carbon beds for the removal of virtually all organic matter from the source waters. These proposals would have used a large quantity of granular activated carbon, but costs and treatment requirements were considered excessive, and the proposals were subsequently withdrawn.

During the comment period, Calgon Corporation proposed a simpler treatment procedure involving the replacement of sand in the existing sand filters with about a 3-foot depth of granular activated carbon.

Advantages: Shallow bed carbon treatment will

- adsorb and remove most of the toxic chlorinated organic contaminants of concern
- can be put into operation quickly
- requires small capital outlay
- minimizes taste and odor
- affords temporary protection from chemical spills.

The EPA reproposal of May, 1979, embraced this concept together with a mandatory requirement to treat all drinking water supplies derived from certain designated "vulnerable" river sources with activated carbon. However, by August, 1979, this proposal appeared to be de-emphasized and was replaced in December, 1979, by emphasis on groundwater contamination. EPA will probably issue an Advance Notice of Proposed Rulemaking in November,1980, containing six proposed MCLs for specific organic chemicals. Any decision on the use of activated carbon technology will not be made until 1981.

Cost and Effect of EPA Regulatory Delays

As previously stated, it will take more than six years for the trihalomethane regulations to move from initial draft to implementation for 50 percent of the population with no significant change in EPA direction or emphasis. How long will it take to get a comprehensive surface and groundwater organics removal regulation in place? EPA, after six years of effort on surface water, has shifted its emphasis to groundwater contamination, and it will be some time before regulations will require treatment for the removal of organic contaminants in surface and/or groundwaters. Compliance with such regulations will be still farther into the future.

Effect of Regulatory Delay

Policymaking is always subject to many legitimate influences that produce delays. However, delay--irrespective of the reaons--produces devastating consequences on companies that gear up to service a regulatory-controlled market, only to discover that the prospect for a developing market fades into the future at a rate equal to the passage of time. Thus, having invested the capital and hired or trained the expert staff, there is no sustaining income. For this reason, the environmental industry is being abandoned by a number of companies.

Calgon believes there is a strong future for the environmental control business. But there can be little question that delayed enforcement and delayed regulations have affected our business negatively. From 1973 through 1975, we made a series of major plant expansions in anticipation of substantial demands for granular activated carbon in the treatment of drinking water, but this demand has not materialized.

Another difficult aspect of servicing a regulatory-controlled market is the on-again, off-again nature of regulatory policy. Changes in direction may well be necessary from time to time, but it would be preferable to have more consistency in regulatory implementation and to defer announcement of proposed regulations until there is agreement within EPA on a given policy. Otherwise, the result is needless confusion both for purchasers and suppliers in industry. Without a reasonable degree of confidence and constancy, suppliers to the environmental controls industry will be properly hesitant to put dollars and technology on the line. The result will be a thinning of the ranks of those who can service this industry and a reduction in the opportunity for technical innovation.

Effect of News Media Sensationalism

Another very disquieting aspect is the sensationalism associated with Love Canal, Three Mile Island, and others. Calgon has been involved with the cleanup at Love Canal from the beginning and has spent a lot of time and money to ensure that our carbon handling and regeneration procedures are safe for our staff, the communities adjacent to our reactivation facilities, and the environment before accepting any Love Canal carbon for regeneration. Nevetheless, our mere association with Love Canal enormously complicates our business operation. As soon as Love Canal is mentioned, people located miles from our plant begin to feel ill, and the press, the State, and everyone becomes concerned--all to no avail, because there is no unique problem relatting to Calgon's Love Canal business.

After all the Love Canal publicity, it is finally reassuring to find Barbara Blum saying, "Overreacting to chemical contamination incidents like the one at Love Canal may cause a chemical phobia that impairs our ability to deal sensibly with cleanup and control of wastes. . . . But because of the anxiety generated by Love Canal, we are confronted with a public crying out for Government to dispose of these dangerous wastes--while saying, at the same time, Not in my backyard." If this trend continues, we at Calgon may elect not to get involved with the next Love Canal, which will leave regulatory and local agencies without the activated carbon technology which is vitally necessary to contain Love Canal-type drainage wastes.

Finally, EPA needs to consider giving a pat on the back to those companies who do a good job of pollution abatement and those who assist in pollution abatement, instead of only publicizing those in industry who do not live up to EPA expectations. A majority of companies in responsible industry strive to live by the letter and spirit of regulations--often doing a better job of pollution abatement than our Federal and municipal installations. EPA can help industry and its own image by giving equal weight to pointing out those who are doing a good job and those who are not.

THE IMPACT OF REGULATORY POLICIES ON THE DECISIONS OF PRIVATE ENTERPRISE

Donald D. Marple, Product Manager
Municipal UNOX Systems
Linde Division, Union Carbide Corporation

It was Voltaire who said "If you would talk with me, define your terms." In doing some talking here, I think it is appropriate for me to define my terms. First I speak as a representative of suppliers of equipment and services to the pollution control industry, more specifically to the municipal wastewater treatment industry. These companies generally supply to the owners or the constructors of wastewater treatment plants as opposed to the designers. While there may be some intercourse with designers, the equipment and services are either provided to the construction contractor building the plant or the owner during and after construction. Supplied to these users and consumers are process designs, equipment, engineering and technical services for construction operations, instrumentation, construction and operating supplies, testing materials and other equipment, and services necessary for the construction and operation of municipal wastewater treatment plants.

A number of these firms may supply the same products to other industries also.

Almost without exception, these suppliers deal with scarce resources to develop their product. By that I mean the suppliers compete with other divisions or departments of a large company for funds for capital expenditure and for expenditure on the necessary research, development, marketing, and technical services to produce and supply a product. In the case of a small firm with few or a single product, they compete for the funds of venture or investment bankers. In short, there's not enough money to go around, and the more profitable enterprises will stand first in line.

Next, these firms are all accustomed to operating in the more or less the free market that we have in this country, making decisions on the basis of return on investment in resources - capital, personal, or technical - and making decisions between alternates on the basis of not having enough resources to do everything that could be done.

Third, these firms have a more or less long-term outlook. That seems to be the trend in companies these days: Everybody wants a five-year plan. But let's remember that the interval from inception to payback in new product development is a long one. By the time an R&D product is developed, funded and completed, and the product is marketed, sold, and the money begins to come in, there is at least a five-year period when the product is a cash drain on the investor. And, the longer this period, the higher is the cost of bringing the product to market.

These firms then function as entrepreneurs and strategists determining where the market is, what profits can be realized, and what the chance of success or failure may be in their efforts to make a profit. Then they have to take their chances on being able to execute the design for the product to bring in a profit.

With this definition then, the discussion begins with the year of 1972 when Public Law 92-500 was passed. This law mandated a lot of work to be done to clean up the nation's wastewaters until they were fishable and swimable, and that more and new resources were needed to do this: There were not enough manufacturers, engineers, and operators to do the job. More people had to be brought into the field. The basis, then, the demand for these products was the mandated requirements for fishable, swimable waters and for secondary treatment by industry and municipalities to be in place by mid-1977. At that time, the general assessment of the observers of the industry was that the 1977 date would not be met; it was thought that this was simply too much of a task to be done in five short years; it was also known that the law was written in a goal-setting atmosphere. Industry observers who surveyed the market at that time thought that there would be a 10- to 20-year period of high demand before the objectives of the law were met. For the next several years, the enactment of this law led to an increased pace in design and construction of publicly owned wastewater treatment plants. The market forecasts began to come true.

But beginning in late 1975 and early 1976, the increasing regulatory requirements and widely varying funding levels, and the conflict over the amount of funding to be provided, severely slowed this activity and reduced the market. At the same time they increased the costs of serving the market by prolonging the period between the beginning of the cost-effective analyses and the end of design. This downward trend continued through the next three years. More than just diminishing the size of the market, these increasing regulatory requirements, the delays caused by waiting for the regulations to implement the 1977 changes in the law, and the deleterious impact of the retroactive application of these requirements have disillusioned many who have tried to forecast this marketplace. This is accentuated by the inability of the program to obligate the funds required in a timely and efficient manner. While enormous funds are unobligated in some States, other States do not have the funds necessary to carry out the water cleanup programs. The funding freeze that took place in early 1980 simply shut down the program in close to two dozen States. At that time, about two billion dollars of fiscal year 1979 funds were unobligated, of which over one billion dollars were located in five States. Twenty States did not have enough money in their fiscal year 1979 funds to complete a medium-size project; on the other hand, the five or six States that had most money continued unable or unwilling to obligate these funds to the necessary wastewater treatment and cleanup within their borders. It seems that the unobligated fiscal 1979 funds, instead of going back for reobligation to the States that have complied with the program, will remain with the States who have been unable or recalcitrant to comply with Public Law 92-500. Such deferral punishes those States and localities that have complied with the program. Those that have gone ahead and built the plants are now paying for the operation of cleaning up the nation's wastewater, while those who have held back and continued to pollute are going free.

The important thing is the market. The effect of these year-by-year

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changes, regulatory impediments to action, and the successful resistance of a number of States and communities lead to an ever-widening gap between the conception and the achievement of clean water standards. However, from the viewpoint of the manufacturers and their capitalists, the effect is that the market ceases to be predictable. No one can say what the financial obligation is going to be from one year to the next; no one can say what portion of this money will be spent on plants, sewers, or engineering services. No one, in effect, can say what next year's market is going to be.

Thus it becomes impossible for a manufacturer to intelligently assign resources to this marketplace. Who is going to build plants to manufacture equipment for which there may be no market next year? Who is going to assign engineering and technical expertise to provide information for customers who may not have the funds or the ability or the desire to comply with the needs of the program?

I want to emphasize that in no way should suppliers of equipment and services to this marketplace demand or even expect a set market; this is not a public works program. If the Federal Government and the U. S. Environmental Protection Agency should decide that all of this work can be done without equipment or with the lowest cost, cheapest equipment money can buy, then those who supply these systems and this equipment will comply with needs of the marketplace or go elsewhere.

If the resources of private industry are important to the achievement of the goals of the program, then there must be a reasonably predictable marketplace. If it is predictable, manufacturers will find ways to service it to more or less predict activity levels, and to allocate the proper resources at an acceptable profit. Some may overforecast and some underforecast, and those who do will suffer to some extent; but basically, a reasonably predictable market leads to reasonably efficient services. An unpredictable market such as we have now leads those firms who are careful about the allocation of their resources (and some would say those who have the best resources) to leave the market rather than place their capital, equipment, and people in the precarious position of not knowing whether or not the market will sustain the effort they have assigned to it. Manufacturers used to dealing with a demand market and used to operating by applying resources before the final sale is consumated -- resources of research and development, engineering assistance and marketing -- are disadvantaged by the unpredictable trend toward purchasing decisions made solely on lowest initial cost. Since 1976, a number of quality suppliers have reduced their efforts necessary to bring technical services and quality to the marketplace -- the public user -- because it is difficult to earn a return on the research that must be dedicated to doing this.

In 1980, there is some evidence that the pendulum may be swinging back. There is recognition of the value of competition among quality suppliers, and it is being encouraged by the American Consulting Engineers Council, the Associated General Contractors, the EPA, and, I believe, the Water and Wastewater Equipment Manufacturers' Association (WWEMA). In certain cases those who bring innovative technologies to the marketplace should perhaps be allowed to be the sole source for systems and equipment with, of course, appropriate safeguards.

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But significant damage to the program has probably already taken place; the need for innovation and for successful plant operation can only be helped by making the market for suppliers of equipment and services a reasonably predictable one, and if this is to be done, more changes have to take place.

Necessary ingredients for a revival of interest are seen to be

- The perception that continued funding is the most likely occurrence. There needs to be an end to the continuing squabbles in Congress over the liability of the Construction Grants Program and an end to uneasiness whether someday, without notice, Congress may not appropriate money for plants yet to be built.

- The perception that the equipment market is not solely a market for low initial cost equipment. With the EPA program requirements memorandum on qualifications procedures, some of this fear has been allayed; however, there must be the increasing use of this procedure, and an increasing recognition of the value of quality suppliers to the marketplace if they are to be expected to remain.

- The perception that new product development can be profitable. For this to be realized, the manufacturers must perceive both a relatively long-term, let's say 10-year, marketplace and the opportunity, in competition with others, to get a return on the resources necessary to provide these products and services.

OFFICE

IMPACT OF REGULATIONS ON APPLICABILITY AND MARKET - THERMAL $DeNO_x$

Norman E. Tadlock, Section Head
Exxon Research and Engineering Company

In addressing the subject, Impact of Regulatory Policies on the Thermal $DeNO_x$ Process, I will trace the history of Thermal $DeNO_x$ from inception to the present. By presenting this historical perspective, it will become apparent how the development of the process paralleled impending or actual NO_x control regulations. In the course of my talk I will discuss:

- Why Exxon researched NO_x chemistry in the early 1970's
- What factors prompted early development/commercialization in 1973/74
- Why the development pace was accelerated in 1978.

The Thermal $DeNO_x$ Process had its origin in the Corporate Research Laboratories of Exxon Research and Engineering Company. In 1971, fundamental NO_x chemistry was being studied for two reasons: (1) anticipation of the need to reduce NO_x emissions from automotive and stationary combustion sources and (2) anticipation that NO_x removal from flue gas could be a lower cost option than denitrogenation of higher nitrogen fuels expected in the future. Our scientists were emphasizing homogeneous gas phase reactions as a potential means for avoiding problems foreseen with catalytic systems. This research led to the discovery that NO_x could be reduced by NH_3 to N_2 and H_2O over a narrow temperature range, the optimum temperature being 900-1000°C. Further laboratory study revealed that the temperature range over which ammonia injection could be used to efficiently reduce NO_x emissions could be extended downward, as low as 700°F, by the judicious addition of hydrogen or various hydrocarbons.

The favorable temperature range for this NH_3-H_2-NO_x chemistry was recognized as potentially forming the basis for a NO_x reduction process for stationary combustion sources such as utility boilers or industrial process heaters/boilers. It was decided to pursue this technology because the NO_x emission standards proposed for boilers in Japan appeared to be too tough to be met solely by the use of combustion modifications such as staged air combustion and flue gas recirculation. With Exxon-affiliated Japanese operations facing these stringent NO_x emission regulations, commercial development of the Thermal $DeNO_x$ Process, as it came to be called, was spurred onward.

By late 1972, the novel flue gas cleanup scheme had already been investigated experimentally in a 1 MBtu/hr fire tube boiler confirming that the process could offer significant NO_x reductions in other than the small, plug flow laboratory reactors. The scientific effort continued into 1973, centered on gaining a better understanding of the basic thermodynamics and kinetics of this NH_3-H_2-NO_x chemistry. Simultaneously, engineers were evaluating the influence exerted by the key operating variables on the utilization of ammonia in the reaction zone.

It was recognized early that there were a number of major factors affecting Thermal $DeNO_x$ performance, including:

- flue gas temperature
  + with or without hydrogen
- residence time at temperature
- temperature profile
- initial NO_x
- NH_3/NO_x ratio
- mixing.

In early 1973, engineers began investigating process parameters on a 30 MBtu/hr test furnace (Fig. 1). During 1973, engineering studied the problems associated with mixing the reactants into the flue gas of full-scale units, investigated associated corrosion/fouling problems, and examined the economics of the system. In the course of this work, a major boiler vendor was involved to gain a better understanding of applicability of the process to utility applications and to assist in preparation of cost estimates for equipment associated with the process.

Results from this research and development effort of 1973 were encouraging enough to prompt a full-scale commercial demonstration by the Japanese affiliates, Toa Nenryo Kogyo Co., Ltd. and Tonen Sekiyu Kagaku K.K., in a 70 t/hr, oil-fired steam boiler in Kawasaki. This demonstration took place in August 1974. Continued pressures to reduce NO_x in Japan led to a number of retrofit utility and industrial Thermal $DeNO_x$ installations there from 1975 through 1978. Meanwhile, R&D continued to improve understanding and performance of the process and to support the commercial installations in Japan. Included in this development effort were jet mixing studies conducted in a specially designed wind tunnel at our engineering center.

Performance of Thermal $DeNO_x$ systems in initial commercial applications is shown in Figure 2. It should be noted that the data presented are representative of our earlier mixing technology, and, therefore, do not reflect performance improvements achieved within the past year. Further, it should be apparent that the specific configuration and local flue gas conditions encountered in each application will govern the system's effectiveness.

While U.S. emission regulations thus far had not dictated that NO_x controls more stringent than combustion modifications be required, the expectation of tightened NO_x emission regulations prompted testing on two

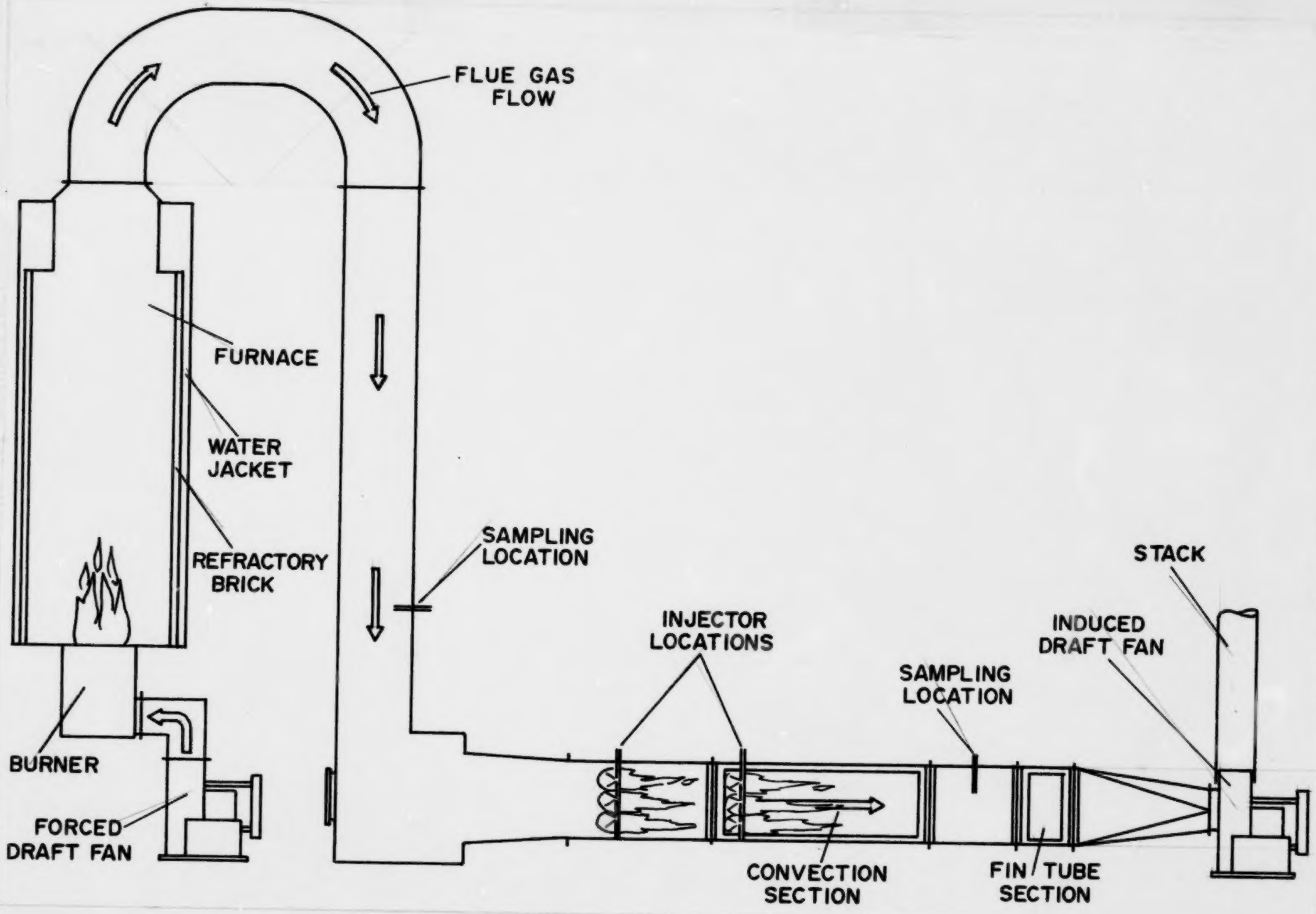
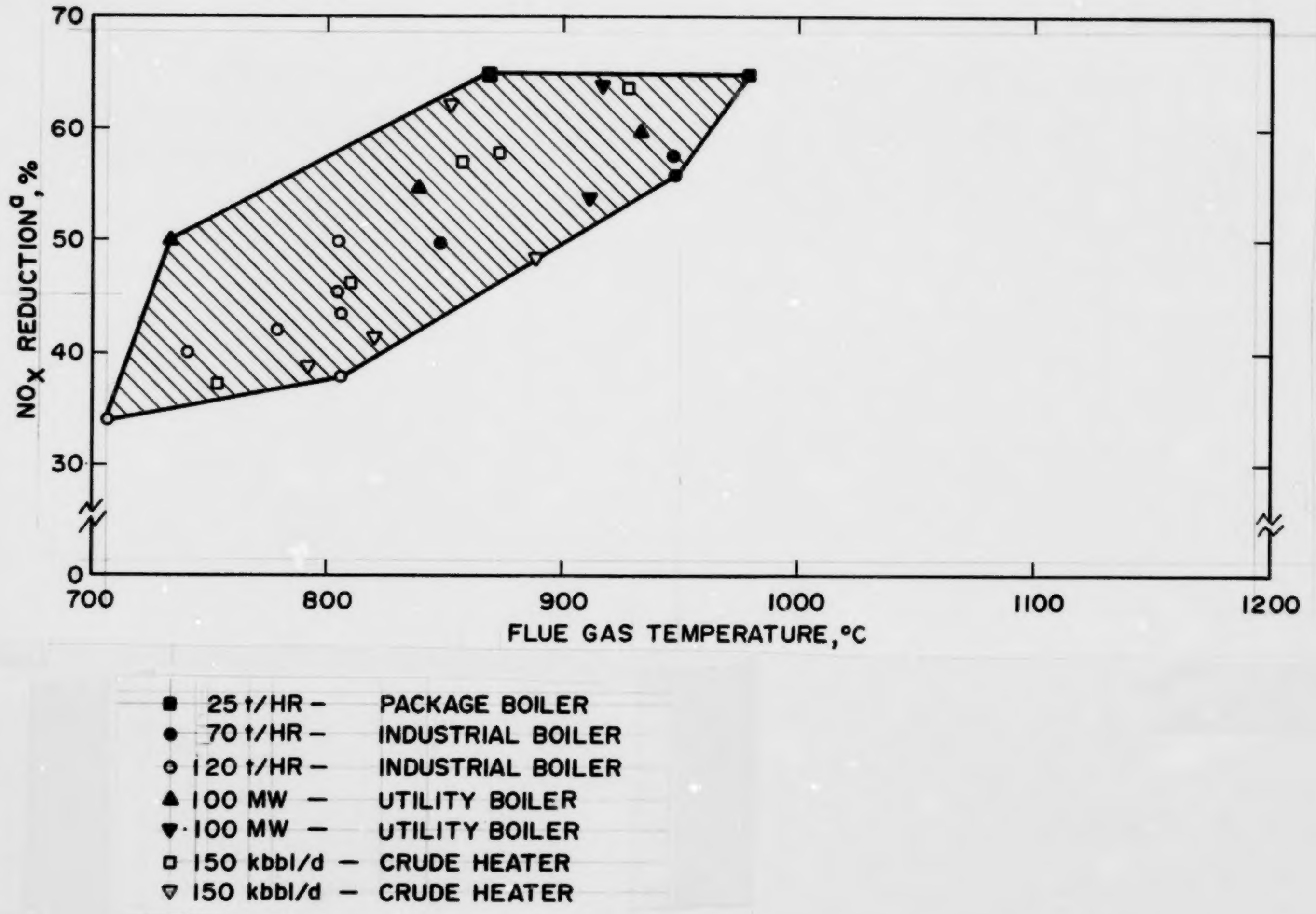

FLUE GAS FLOW
FURNACE
WATER JACKET
REFRACTORY BRICK
BURNER
FORCED DRAFT FAN
SAMPLING LOCATION
INJECTOR LOCATIONS
CONVECTION SECTION
SAMPLING LOCATION
FIN / TUBE SECTION
INDUCED DRAFT FAN
STACK

Figure 1. Thermal DeNO$_x$ Test Furnace.



[a] Performance on any specific unit is a function of design and operating parameters

Figure 2. Performance of Thermal DeNO$_X$ systems in commercial applications based on earlier mixing technology.

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varied fronts in 1977. A demonstration of the Thermal $DeNO_x$ Process was performed for Chanslor-Western Oil and Development Co. on a 50 MBtu/hr Struthers Thermo-Flood oil field steam generator by KVB, Inc. in 1977. For this short-term demonstration, significant NO_x reductions, as much as 70%, were achieved using a standard North American burner. Also in 1977 under joint sponsorship by the Electric Power Research Institute and Exxon, KVB's pilot-scale coal combustor was used to demonstrate that NO_x reductions and byproduct emissions obtained with ammonia injection into coal-derived combustion products were similar to those obtained from oil- and gas-fired systems.

The 1977 Clean Air Act Amendments resulted in rigorous review by the U.S. Environmental Protection Agency of all State Implementation Plans and in Federal pressure for the nonattainment Air Quality Control Regions to develop plans to bring their regions into compliance. Of the four Air Quality Regions in the nation that exceeded the maximum ground-level concentration set for nitrogen oxides by the National Ambient Air Quality Control Standards, only the South Coast Air Quality Management District decided to reduce emissions of nitrogen oxides by controlling stationary sources; the other three plan to control mobile sources. As a result of this Federal pressure, the South Coast Air Quality Management District in August 1978 promulgated Rule 475.1 that required all utility boilers in the district to reduce their emissions of nitrogen oxides to 50% of the January, 1978 level by January, 1982 and to 10% of the January, 1978 level by January, 1990. The Air Resources Board, in public hearings, identified Thermal $DeNO_x$ as the basic technology available to achieve 50% reduction of nitrogen oxides. The Board also identified supplemental control technologies that might be used in connection with Thermal $DeNO_x$ if required to achieve 50-percent reduction. In addition, it was expected that Rule 475.1 would be expanded to require similar reductions of nitrogen oxides on large industrial boilers and process heaters.

In view of the implied, rather extensive use of Thermal $DeNO_x$ on existing utility boilers in Southern California, a concentrated engineering development program was undertaken in early 1979 to meet this challenge with the goal of further improving $DeNO_x$ performance. This development program primarily involved engineering personnel with support as needed from our scientists. Major areas of study included in the accelerated program were:

- Mixing/Kinetics Modeling - The goal of this program is to develop jet mixing/kinetics computer models to predict Thermal $DeNO_x$ performance accurately for all potential applications.

- Process Variable Studies - This program is studying the effects of flue gas velocity in the injection plane, very low O_2 and high NO_x concentrations in the flue gas, air carrier vs. steam carrier, carrier temperature and rate, jet orientation, and new jet mixing concepts.

- $DeNO_x$ Emission and Foulants - This program includes ammonia breakthrough testing, evaluation of ammonia analyzers and an evaluation of the effects of ammonia salts formation, deposition, and corrosion.

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- Performance Prediction and Design Procedures - This program involves the combination of theoretical and experimental results to improve and expand current design procedures for grid jet coverage, carrier heatup, DeNO$_x$ performance, and ammonia breakthrough prediction.

Test facilities utilized in this R&D program consist of the 30 MBtu/hr test furnace (Fig. 1) previously mentioned and a "high velocity" wind tunnel especially constructed in 1979 to simulate flue gas velocities prevailing in many of the utility boiler tube banks in California's South Coast Air Basin.

As a result of this concentrated R&D program, improvements to the process performance have resulted. Table 1 summarizes some recent test furnace results stemming from an improved mixing design. Coupling the improved mixing concept with a second stage injection of hydrogen to promote NO$_x$ reduction at lower flue gas temperatures, yields even further DeNO$_x$ performance. It should be noted that these test furnace results represent favorable residence time and temperature level, as well as uniform temperature distribution. Incorporating the newer mixing technology on commercial units will result in less significant improvements than shown in Table 1 due to less-than-optimum operating conditions.

The evolving California regulations now imply a substantially smaller role for Thermal DeNO$_x$ in controlling NO$_x$ emissions from their existing utility boilers. But the Thermal DeNO$_x$ performance improvements prompted by the California regulations have better positioned the technology for application to industrial sources and coal-fired boilers in the future. Table 2 summarizes the variety of applications for which the technology is being used, ranging from glass-melting furnaces to utility boilers. Among others, the improved mixing technology is being incorporated in the California utility boiler currently being retrofitted with the Thermal DeNO$_x$ Process. Not surprisingly, the U.S. applications have been limited to California thus far because of their more stringent controls of NO$_x$ emissions.

In summary, research in NO$_x$ chemistry began in the early 1970's in anticipation of the need to reduce NO$_x$ emissions and this research resulted in the Thermal DeNO$_x$ Process. Development pace of the technology paralleled regulatory events in Japan and the United States. At home, NO$_x$ control regulations have evolved slowly and the final form is still unclear. The market for Thermal DeNO$_x$ remains uncertain due both to the aforementioned regulatory uncertainty and advancements made with competitive technologies.

One clear lesson that has been learned from tracing the history of Thermal DeNO$_x$ is that development strategies need to be flexible, allowing the technology to be slanted to previously unanticipated applications as emission regulations progress.

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Table 1. Test furnace results of recent technological improvements.

		Percent NO_x Removal
Early Mixing Designs (Without H_2 Injection)	-	58
Improved Mixing (Without H_2 Injection)	-	68
Improved Mixing Plus 2nd Stage H_2 Injection	-	77

Conditions:

Initial NO_x - 200 vppm

NH_3/NO_x - 1.5 mol/mol

O_2 - 3 vol %

Residence Time - .066 sec

2nd Stage H_2/NH_3 - 0.5 mol/mol

Temp. @ Pt. of NH_3 Injection - 1790°F

Table 2. Summary of Thermal DeNO$_x$ experience for both oil and gas-fired units.

	(Numbers of Units) Operational	Construction Phase	Design Phase
Japanese Industrial Boilers	3		
Japanese Utility Boilers	5		
Japanese Petroleum Heaters	4		
California Oil Field Steamer (Demonstration)	1		
California Flat Glass Melting Furnace (Demonstration)	1		
California Petroleum Heaters	2	19	5
California Utility Boiler		1	
California Industrial Boilers		3	
California Incinerators			2

Session IV
Fiscal and Marketing Issues in Technology Innovation

Presiding Chairman:
David Gibbons
Chief, Environmental Branch
Office of Management and Budget

INNOVATION, PUBLIC POLICY, AND THE NATION'S ECONOMY

David G. Soergel, President
DGS Associates

INTRODUCTION

As the title suggests, this paper contains an analysis of several complex policies, identifies a National Innovation Policy that results from their interactions, and assesses its impact on our economy.

The Policy is particularly interesting. It invisibly inhibits all civil and regulatory agencies in ever achieving their important national goals innovatively, effectively, and efficiently. It just as much inhibits the U.S. Department of Energy (DOE) in achieving energy independence, as the U.S. Environmental Protection Agency (EPA) in achieving a less polluted environment.

Worse, it goes beyond governing only public sector innovations. It governs all innovations, be they aimed at private or public innovation consumer markets.

It is a Policy which is unintended, invisible, and nonlegislated. It favors business expansions over new enterprise starts, extends this favoritism into $100 billion of annual Federal procurement, and authorizes the expenditure of taxpayers' money to start new ventures, yet absolves those who spend it of any responsibility to finish what they had started. It comes from opaque interactions between U.S. tax, procurement, and research and development (R&D) policies.

THE POLICY'S ROOTS

The Policy had its roots in labor union legislative successes. For many years, labor unions have successfully promoted national labor policies which standardize and govern labor's cost within entire industries and delete labor's cost as a factor in competitive pricing. Left mainly with overhead cost reductions to gain competitive price advantages, corporate managers have eagerly sought ways to automate "anything that moves" at a cost at least comparable to labor's, and usually much less.

Technology applied to the back-end of innovation--automated production--has, of course, yielded some production operations not possible by labor at any costs, and gained significant near-term price benefits for consumers. But, unfortunately, these attractive benefits often come at a long-term and unacceptable price.

Not only have labor unions concentrated economically, so have entire industries. Large firms with more access to private capital markets than smaller competitors gained relative price advantages, and increased market share, and an even greater market share that comes from increased economies of scale. Big firms got bigger and still bigger; taken to its logical conclusion, entire industries became economically concentrated. Today, nearly 80 major U.S.

FORM FOR TPA CONFERENCE MANUSCRIPTS

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industries are economically concentrated with four (or less) very large firms supplying 60 percent (or more) of the industries' total market. This is hardly capitalist enterprise as originally intended.

The near-term benefit of consumer price reductions brought about by automation has now matured to its predictable long-term detriment. Entire industries, locked into many years of "old" technology production to return to shareholder equity the high, up-front automation investment costs, have lost labor's flexibility. They no longer can adapt rapidly and efficiently the production operations to new technological opportunities as they may unpredictably appear, and to new technology production.

Our economy is stagnated mainly because of capital-intensity stagnation. We have reached the point of diminishing returns in further automating the production of "old" technology products to gain even more price reductions. A new technology emphasis is needed.

Major productivity improvements of the past traditionally came from applying technology internally to create and develop new products--transistor instead of vacuum tube technology for example--rather than for applying technology externally to production--the history of auto manufacturing, for example, where initial price reductions were substantial, but gradually leveled-out to the industry's current internal technology stagnation.

In order to sharply increase our productivity rates, motivate enterprise, spur competitiveness, and ultimately improve our world trade position and revitalize our economy, brand new products that require brand new capital investments for production are sorely needed. New production capital must drive out the old, and Joseph Schumpeter's "creative destruction, the essential fact about capitalism" must be purposely instituted in public policy. The promotion of technology, enterprise, competition, and innovation should be a key thrust of such a policy.

A problem stands in the way, however. The invisible, nonlegislated National Innovation Policy works in an entirely different direction. It fosters "capital protection", not "creative destruction." During the many, necessary, years producing "old" technology products, attractive, new technology products that are not producible by the large firm's capital must be kept out ot its markets. Otherwise, a large firm's products could lose sales to these new, more attractive products--severe losses,many have to be taken--and the large firm's very existence could be brought into jeopardy. This happened, for example, when Chester Carlson's Xerox was introduced into office equipment manufacturers' markets. This is precisely what the Policy is aimed to do: It protects already existing production capital from entrepreneurial challenge during an extended capital cost-recovery period. It keeps our 1980 "Chester Carlsons" out of (going into) business.

The erosion of capitalist enterprise caused by the Policy's lock-out of new enterprise has some very serious long-run implications. Capitalist enterprise is the only economic system yet instituted by any government which both depends on and fosters individual liberty and economic freedom. There simply are no others. And "creative capital destruction" brought about by new

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market entries must be purposefully fostered by public policy for a free nation to remain free in the future.

WHO CHALLENGES CORPORATE ECONOMIC POWER?

To round off these introductory political economy observations, just who in America is most likely to challenge corporate power and industrial concentrations? The answer to this has been known for some time and it is not the Federal Trade Commission or other Government regulatory interventions into the capitalist enterprise economy as some still foolishly believe. The challengers are new technical enterprises, financed by risk-taking individuals. In the dimming past, these have introduced more major innovations and created more new jobs than all the long-established firms taken together. They have put old, long-established firms out of business because of the companies' inability or reluctance to introduce new technology products, and have created entirely new industries.

Unfortunately, important as they are to the survival of the capitalist enterprise system, and ultimately our liberty, new technical enterprises have been nearly driven out of (going into) business. In 1969, 204 companies made public stock offerings. By 1975, none were offered, though, lately, capital gains tax reduction from 49 percent to 28 percent has somewhat turned around this disparaging situation--called "national malaise" in one presidential candidate's terms.

Nonetheless, the Policy still remains, and rather than challenge economic concentrations, new technical enterprises are often acquired by big firms once they invade their turf. Most end up feeding the large firms' growth instead, typical of any natural ecological system wherein weak members are gobbled up by a few, powerful members. The new, novel, and major innovation originated by the acquired new technical enterprise may or may not be introduced by the large, capital-intensive firm that acquired it; but if introduced at all, the schedule for market introduction will be keyed to the acquiring firm's capital depreciation schedules, not to schedules of consumer needs or national goals, nor to schedules forced by domestic or foreign competition, nor to the earlier introductory schedules of other technological opportunities as they may unpredictably arise. Capital protection remains deeply ingrained in America's economic system promoted by the Policy. Little has fundamentally changed by tinkering with one tax code provision.

EPA'S CHALLENGE

You may wonder what all these political economy comments have to do with EPA. I happen to believe that they have a lot to do with whether EPA can ever achieve its important antipollution goals innovatively, effectively, and efficiently.

Perhaps I can best explain by using a catch-all term, "Yankee ingenuity," spoken almost wistfully these days, like referring to a dear, departed friend.

Yet it is "Yankee ingenuity" which EPA must somehow harness to achieve its statutory mission. EPA's innovation policy must motivate unknown people to introduce unknown and less polluting innovations, and unknown consumers to

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purchase them when they are offered for sale. Its technology base is truly the nation's, and its innovation consumer marketplace is distributed throughout all 50 States.

More close to home, EPA's anti-pollution goals must constrain the goals of DOE, Housing and Urban Development (HUD), and the Department of Defense (DOD). Indeed, they must constrain the goals of all Federal agencies. Not any civil or regulatory agency should innovate "what it thinks best" without being constrained by EPA's antipollution goals. When considering both private and public sectors, EPA, in my opinion, has one of the formidable challenges of all Federal agencies, with the exception of the State Department's and DOD's in reining in the Soviet Union's hegemony.

Perhaps the President's economic advisor, Dr. Charles Schultz, said it best when he delivered the 1976 Harvard University Godkin Lecture. He claimed the most important challenge facing all civil and regulatory agencies is to create and introduce new public policies. Such policies must "motivate" public goals to become "private interests," without resorting to what he called "command and control" methods. The coercive approach that underlies technology forcing standards--an approach often favored by the legal community including over 65 percent of our congressional members--just won't work in America.

COMPLEX POLICY COMBINATIONS

I proceed now to an analysis which demonstrates how U.S. tax, procurement, and R&D policies do indeed combine and form a nonlegislated, invisible National Innovation Policy--a policy which protects current capital from entrepreneurial challenge during an extended capital cost-recovery period. And I hope to demonstrate also that tinkering with anyone of the three policies out of context with the others will do little towards remedying "national malaise" and giving hope to individuals who wish to venture their own ideas as a means of advancing their economic positions.

To clarify the analysis, I must introduce another term possibly not as familiar as "national malaise," but one that you will fully understand, and this is "venture entitlement." When I use it I will be referring to federally-distributed entitlements to advance economic positions from whatever they may be at the moment. For if, indeed, by public policy, some in society are favored over others in advancing their economic positions, we will have discovered a situation of "inequality before the law." Such a statutory inequality, whether visible or invisible, would violate the constitutional rule-of-law which guarantees all citizens the right to stand equally before all laws of a free and democratic society. It could possibly be even judged unconstitutional if brought to a Supreme Court test.

INNOVATION AND ITS FINANCING

To isolate, analyze, and synthesize public policies which do distribute entitlements to advance economic positions, I choose to center my discussions on innovation's commonly accepted S-curve cost accumulation, and key cost accumulation to sequential design-progression phases. This is shown on Figure 1.

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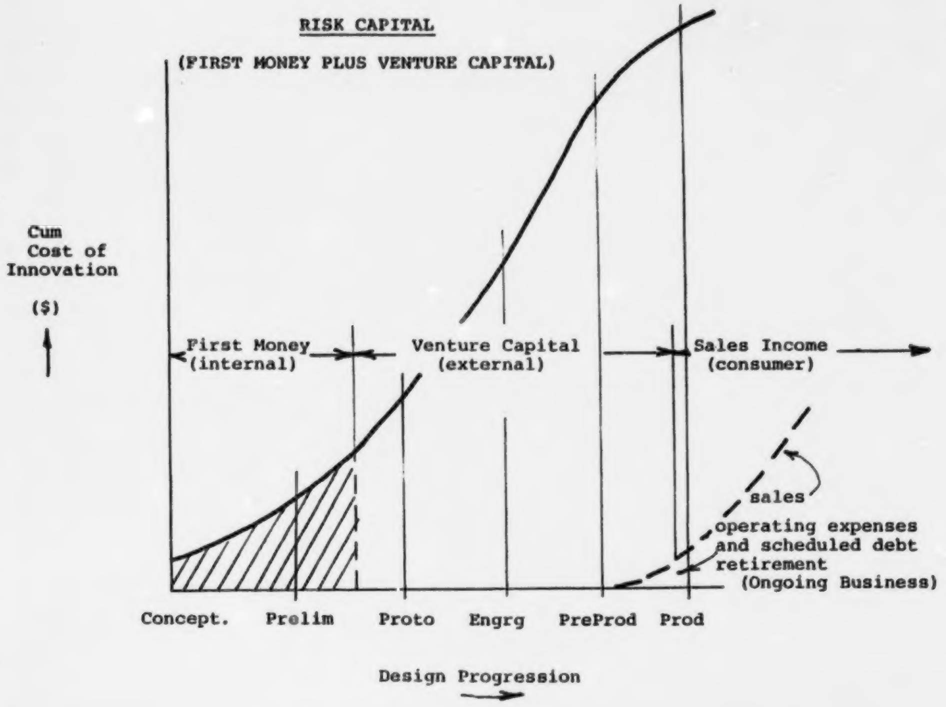
FIGURE 1.



DGS ASSOCIATES

The curve is obviously idealized for illustration purposes. Actual cost accumulations are rarely as smooth--an uneveness is caused by the "learning process," characteristic of all innovation when the planned technical direction doesn't work as expected and a new direction must be taken. Also, design-progression phases, as shown, are rarely equally spaced in calendar terms. No dollar values or calendar time schedules are indicated because each project innovation is depicted by its own unique cost and schedule data.

Once an idea is selected for resource expenditure, we move into the earliest beginnings of innovation's cost accumulation. At this point it is important to ask, who creates ideas? Who selects and finances them? And who "moves" selected ideas into their intended consumer markets?

Ideas come from the minds of people called "inventors." Ideas proposed by inventors are usually selected by other people and are financed from out of their pockets. They are called "investors" or "venture capitalists."

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Inventors and venture capitalists are usually not the same people. Also, inventors are not necessarily innovators. Innovators "move" an idea into its intended market, and the inventor will not be necessarily employed by the innovator's organization.

I choose the term "first money" to identify money which comes from either or both the inventor's and innovator's pocket. Others may call it "seed" capital or "up-front" expense.

The location of the ordinate which separates first money from externally-supplied venture capital has been arbitrarily placed, and to explain this arbitrary placement requires a short discussion of the difference between venture entitlement and economic position.

Obviously, innovative individuals or firms more wealthy than others (that have a relatively advantaged economic position) can move the ordinate relatively further to the right before outside financial assistance is needed, if all innovate similar ideas. In fact, depending on an idea's perceived full-run resource to bring it to market and availability of first money resources, some entrepreneurial firms and individuals may spend only first money in "moving" an idea all the way to a consumer sale's position. Venture capital would not then be needed and would simply disappear from the chart, leaving only first money and sales income.

At any point in time, all innovators interested in a common consumer market will be distinguishable by different economic positions; or, metaphorically, all the trees in the forest will be of different size. But they will all be entitled to grow larger--some more entitled than others, depending on their locations in the forest.

Thus economic position--a tree's height--and entitlement to advance economic-position--grow larger--are entirely different economic concepts. This is an important economic distinction which we will return to later.

Venture capital financially maintains the momentum of a new idea as it moves towards its intended market. It comes externally from nonassociated investors who judge investing in the proposed venture more in their financial self-interests than other investment opportunities they may have under consideration. These investments come by means of several financial instruments: equity stock for which some ownership of the idea must be given in exchange; unsecured loans called "bonds" which may convert to equity stock ownership at a later time; trade-debt (which means some suppliers deliver at no cost with future pay-back obligation); and secured commercial loans.

These are Wall Street's venture capital financial instruments. They finance innovation, and as can be appreciated when dealing with Wall Street, "there's no such thing as a free lunch." Either ownership dilution or debt, or both, are the consequences of success in gaining Wall Street's venture capital support.

ANOTHER VENTURE CAPITAL SOURCE

I would be remiss, however, if I did not discuss another huge source of venture capital--more than all the first money industry independently supplies. It is not distributed by Wall Street. It is distributed instead by Government and is not labeled venture capital, but R&D. In fiscal 1980, $30 billion venture capital was taken out of private capital markets by the U.S. tax system, centralized in the U.S. Treasury, and spent by Federal agencies to venture ideas with hope of achieving their statutory responsibilities sometime in the future. It is a special venture capital which, by self-definition, brings ideas to only a production position and no further. Wall Street's, on the other hand, may bring ideas all the way to consumer sales, unless failures occur before sales and losses have to be taken by investors.

Government, too, has its special venture capital financial instruments; Federal grants, cooperative agreements, and R&D contracts. These venture capital financial instruments are much more attractive than Wall Street's.

The reason is, if the innovator gains them, no ownership dilution or debt assumption is demanded in exchange. The innovating organization's internal cash-flow is externally supplied by U.S. taxpayers (with exception of cooperative agreements where some cost-sharing is required), and profits or fees may accrue to the innovator's benefit even before the consumer market is reached through production, distribution, and sales (again, with exception of the cooperative agreement).

Obviously, because of their relative attractiveness, Government's venture capital financial instruments will drive Wall Street's out of private capital markets, if and when they are made available by public policy. Like bees around honey, individuals, private firms, universities, and other nonprofit enterprises will swarm around Washington, DC, in hope of gaining venture capital support by means of these extremely attractive financial instruments. They cannot be matched in private capital markets.

Finally, first money, or a combination of first money and venture capital (either is called more generally, "risk capital") may or may not bring new ideas to consumer sale's positions. Nonetheless, even if they do, the firm still is "not-in-business" until sales income provides operating cash-flow and scheduled debt repayments, including interest charges. When a new enterprise reaches this sales income position it becomes an "ongoing business."

And when it does, the U.S. tax code will treat it equally with all other ongoing businesses in entitlements to venture new ideas--that is, in entitlements to expand its business by venturing new ideas, regardless of its sales position or size of the moment. All ongoing businesses will be equally entitled to grow larger; the Fortune 500, and all ongoing businesses of much smaller size.

"SMALL" BUSINESS RULES

Well, not exactly. Some believe that so-called small firms should be given more entitlements to grow larger than firms already large. This belief is embodied in "small" business legislation, and our legal community is having a field day in distributing more entitlements to grow larger to businesses arbitrarily defined as small than is distributed to firms arbitrarily defined as large. This brings us back to the difference between venture entitlement and economic position.

The question of whether public policy distributes equal venture entitlements to all citizens and businesses of a free and democratic society who hope to advance their economic positions, cannot be answered by examining relative economic positions of the moment--that is, by examining momentary relative sizes of ongoing businesses or the relative wealths of individuals. As long as economic positions of the moment were not fraudulently gained, Government can exert no influence over the "means" to the "end" of an individual's or firm's economic position, if we are to preserve economic freedom as a constitutional guarantee.

Nevertheless, laissez-faire economic freedom has yielded some unacceptable social outcomes, toxic waste disposal, polluted air, etc. Thus, with the advent of the EPA, the "means" to the "end" of economic position are indeed, and I happen to believe appropriately, constrained. Here it is important to point out that "constraining means" is not the same as "dictating means" -- another important distinction. The latter implies that means to social ends are already determined; the former implies that constrained means to the same social ends are sought.

Rather than examine relative economic positions to address the question, we must instead examine public policy venture entitlement distributions--who gets them and how much they are benefited relative to others. Metaphorically we ask, are some 100-meter sprinters entitled to a head start when all line up to "race" their ideas to market?

To address this economically, we isolate two distinctly different economic activities; firms of any size already in business, and entrepreneurs who are not yet in business, but who hope to be in the future. And we ask, are ongoing businesses entitled to a head start over entrepreneurs when all line up to "race" their ideas to market?

And indeed they are. The tax code tells us that ongoing businesses can save some of their net taxable profits taxed at a 46-percent maximum rate. It also tells us that the taxable incomes of entrepreneurs while previously employed would have been taxed at a 50-percent maximum rate. Or more important, the taxable income of venture capitalists is taxed at up to a 70-percent maximum rate. Thus on a maximum income tax rate basis, the tax code clearly favors corporate savings over the savings of our nation's risk-takers, and equity represented by savings is an extremely important resource for venturing ideas because cash-on-hand is needed to pay internal costs and invoices for purchased services, materials, and equipments.

It is indeed strange that our country's risk-takers, those who gain income from loan interest and equity stock dividends--precisely the people who entrepreneurs must approach and attract to their new ventures--are the most highly taxed individuals in our society. And as a further insult, Congress has labeled their income "unearned," which hints at how Congress values income earned by financially helping others venture their ideas.

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While this is bad enough, the tax code puts ongoing business still further ahead at the start. When entrepreneurs leave employment to devote full-time to their new ventures, they are left with family after-tax savings and refinanced or sold personal property, such as autos and houses, which has also been accumulated from after-tax income. This is what they must use as cash-flow to finance a costly search for outside investors. They have no other choice, not having yet found outside investors or reached a sales income position.

Not so ongoing businesses; The tax code permits tax-deductibility of any consumer sales income the company elects to spend for venturing new ideas. This tax code feature, added to favored savings, puts taxpayers in a position of subsidizing their venture expenses.

To illustrate this tax deductibility feature that adds to favored corporate savings, in 1977, 624 of the nation's largest firms (out of 4 million U.S. businesses) expended $18 billion in nearly $1 trillion sales income to venture new ideas; an amount estimated at about 90 percent of all first money internally incurred by all U.S. businesses in that year. In effect, taxpayers subsidized the 624 firms' first money by about $9 billion in foregone Federal revenue. This observation is not intended to single out the 624 firms. All ongoing businesses of any size may tax-deduct their consumer sales internal cash-flow when it is used as first money to venture new ideas.

In short, firms already in business, regardless of their relative sizes, will benefit by tax code entitlements to expand their businesses--they are entitled to a 10-meter advantage over entrepreneurs at the start simply because they have already reached a sales income position. But these entitlements are denied entrepreneurs who are not yet in business, but who hope to be in the future--they start the race 10 meters back simply because they have not yet reached a sales income position.

When we consider both first money and outside venture capital financial support, the U.S. tax code clearly favors business expansions over new enterprise starts; and small business legislation that is directed to level economic inequalities--to level all the trees in the forest to the ones of smallest size--is yet another example of proliferating legislation which addresses the wrong problem and leaves the real problem unaddressed and buried in public policy complexities. In brief, all the trees in the forest are not equally entitled to grow larger. That is the real problem.

Nobel laureate, Friedrick Hayek, summed up the tax code situation in the following way:

> "The tax system tends generally to favor corporate as against individual savings and particularly to strengthen the position of established corporations against newcomers. The old firms do not need to fear (the newcomers) competition; they are sheltered by the tax system. (Old firms) may with impunity indulge in routine, they may defy the wishes of the public and become conservative. It is true the income tax prevents them too from accumulating new capital. But what is more important for them is that it prevents the dangerous newcomer from

> accumulating any capital. They are virtually priviledged by the tax system. In this sense, progressive taxation checks economic progress and makes for rigidity." (Source: The Constitution of Liberty, pages 320-321)

Unfortunately, wealth redistribution by means of highly progressive individual income tax rates hurts most those people left-liberals had intended to help; namely, low income earners who hope to advance their economic positions by venturing their own ideas, win or lose. They must go into private capital markets earliest of all and seek outside investors who have been made scarce by the highly progressive income tax system. The nation's risk-takers are an increasingly rare "species" endangered by the U.S. tax system.

Hayek also suggested a remedy; namely, if Government took 22 percent of national income for its own operations, the 22 percent would also be the maximum taxation rate on any income, whether corporately or individually earned. In 1970, he was joined in this by another Nobel laureate, Milton Friedman, who also suggested some tax rate progressivity at low incomes to balance out regressive taxes, such as sales taxes and social security deductions.

From total income, individually or corporately earned, would be subtracted the amount spent to gain that income and the difference would be subjected to a flat-rate tax equal to government's percentage share of national income.

Keep in mind, cost to gain income would not include any costs to hopefully gain future income, such as "R&D expenses," nor would home mortgage interest be deductible, philanthropic contributions, and other common tax deductibles found in today's terribly complex code. (Called a "national disaster" by the same presidential candidate who claimed a situation of national malaise pervades our society.)

Conceivably, a large constituency would endorse flat-rate taxation for reasons beyond its obvious comparative simplicity, which is reason enough. It ought to be enthusiastically endorsed by corporations; about 22 percent maximum rate vs. the current 46 percent. It ought to be enthusiastically endorsed by those who gain income by equity investments and risk-taking loans; about 22 percent maximum rate vs. the current 70 percent. Most important, anyone who has an idea ought to endorse flat-rate taxation, because venture capitalists will, with more cash-on-hand, take on more risks and invest in more new ventures. And we all have ideas from time to time don't we?

Under such a policy, the economy would "get going" again. Everyone would benefit, particularly the poor who always benefit by increased economic activity--in jobs and price reductions of goods and services which they otherwise could not afford. It is hardly controversial that very few television antennas can be seen in low-income communities in other parts of the world where capitalist enterprise has not been the nation's underlying political economy.

Nevertheless some important people are not listening to the two Nobel laureates' advice. These are our defenders of economic freedom--our U.S. members of Congress. They apparently are still hung-up on using the tax code for wealth redistributions, a means to an end which hurts most the very people

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wealth redistribution was intended to help. They are absolutely blocked from getting ahead in society by venturing their own ideas, which signifies that "America, the land of opportunity" is really a wistful recall of the past. It is not today's reality.

TWO OTHER POLICIES

Two other policies combine with the tax code to protect current capital from entrepreneurial challenge. One is U.S. procurement policy. It distributes the identical venture entitlement inequalities which are distributed by the tax code. This is because procurement policy is subservient to the tax code in this regard and must be in compliance with tax code venture entitlement provisions. Thus it favors already established Federal contractors in expanding their agency business over new Federal market entries.

Here is how this favoritism comes about, and keep in mind, it comes from the tax code and not from some diabolical procurement policy-maker.

Most Federal procurement is negotiated rather than fixed price competitive, about 85 percent of $100 billion annual procurement expenditure. To simulate the tax code's first money tax-deductibility, an amount of tax-deductible venture expense is negotiated into Federal contracts as an allowable, indirect Federal contract charge. It is money which is added to the total cost to deliver the contracted item, and is spent by the contractor to prepare for and propose new business to the contracting agency.

The only accurate data on how much of these agency new business expenses are indirectly paid the contractor by U.S. taxpayers is found in a annual Defense Department audit. In 1978, $1.4 billion of first money was recovered in the weapon sales prices of fewer than 100 of DOD's largest suppliers. Because the audit stops at fewer than 100, no one is precisely sure just how much total first money was indirectly paid by taxpayers to DOD's overall 24,000 separate contractors.

As can be seen, if a firm is already a defense contractor, taxpayers will indirectly pay its first money to prepare for and propose even more weapon's business. But taypayers do not pay first money to any other companies, not even to large commercial suppliers that may wish to enter DOD's innovation markets for the first time. Their first money comes from private consumer sales.

Entrepreneurs who hope to advance their economic positions by entering DOD's innovation markets are obviously most disadvantaged of all. At the start, they don't have any contracts, Federal or otherwise. Again, they are left with after-tax family equity as their only first money resource to enter the Catch-22 Federal procurement system with hope of gaining some of Government's venture capital. To do so, they must first prove their ideas to qualify for Federal R&D contracts to prove their ideas, a Catch-22 proposition if there ever was one. Most go broke if they are foolish enough to try.

The other policy is U.S. R&D policy. It violates a universally-endorsed management principle. It splits authority to start, from responsibility to finish, and propels our economy towards collectivism and central economic planning. In 1978, out of nearly one million employed scientists and engineers (S&E) who were assigned R&D innovative activities, 300,000 were employed to start new ventures for which they had no responsibility to finish. They were employed by organizations whose capital investments in R&D and production plant, equipment, and other capital assets, such as corporate savings, are not privately owned.

No way literally exists to judge their relative performances to each other or to industrial firms, to decide whether they should stay in business, become larger or smaller, or even how much their S&E employees ought to be paid. These organizations are the so-called "nonprofits," located in both private and public sectors. Private nonprofits, such as universities, of course, don't pay any Federal income taxes, nor obviously do public nonprofits, such as Federal labs, nationalized laboratories, federally-funded R&D centers, and State and Local Government technical organizations.

For example, nonprofits started a supersonic transport that never flew, "new technology" houses that were never bought, and a special city bus that was never produced, yet they still remain "in business" and some have even significantly expanded their operations and raised their S&E pay scales.

And, as might be expected, U.S. taxpayers paid nearly all nonprofit-employed S&E's salaries and fringe benefits--$14 billion Federal R&D was spent in 1978 to finance nonprofits while they started new ventures which they were not responsible to finish. This amounts to an average $46,000 annual, per employee at taxpayer's cost.

This leads to what I believe is an interesting observation: Almost all new ventures in the U.S. are started by Federal agency "peer" or "proposal" committees acting as surrogates for competitive, private venture capitalists; and congressional committees appropriate taxpayer's money to start these new ventures acting as "Boards of Trustees" of a very large nonprofit corporation, perhaps rivaling the Soviet Union in size.

The concentration of nonprofit venture expenses mainly in basic and applied research categories means that nonprofits work in the earliest part of the venturing process, which is precisely where entrepreneurs also work. To them, nonprofits monopolize the "seed" capital which they need to start their new firms.

Of 1978's $14 billion taxpayer-supplied venture capital allocated to nonprofits by the U.S. R&D policy, $8 billion of it financed nonprofit ventures to development positions. The remaining $6 billion was spent by nonprofits to advance their ideas all the way to production positions.

Of course not all new ventures are started by nonprofit technical organizations. Industry starts some too. But industry's first-money expense is mainly concentrated in the development category, and not in basic and applied research categories where ideas are created and some are initially explored. This suggests that industry is either busy finishing the ventures the nonprofits had started, such as nuclear power, or busy product-improving, rather than product-innovating.

By far the most Federal development money is spent by long-established Federal contractors. They already own the innovation machinery which is needed to "move" the nonprofit's early work into consumer markets and, as previously explained, have their first-money expense picked up by the taxpayers. Not owning any innovation machinery at their beginnings, not having their first money-expense picked up by taxpayers, our ambitious and in Hayek's term "dangerous" entrepreneurs are once again left on the outside looking in. They are disadvantaged to the point of exclusion in playing in this stacked-deck economic game. Thus public R&D policy adds a very large measure of capital protection to that promoted by both U.S. tax and procurement policies. A stagnated economy, collectivism, and centralized economic planning can only come from this complex combination of complex policies. And not surprisingly, it has.

SUMMARY

In summary, I hope I have convinced at least some in the audience that an invisible, nonlegislated National Innovation Policy actually exists, and has existed for some time; that its key feature is protection of production capital from entrepreneurial challenge while capital-intensive firms sell "old" technology products over long periods to return initial capital investment costs to shareholder equity, and that capital intensity is propelled by noncompetitive labor costs powered by Federal labor laws, such as the Minimum Wage, Davis Bacon, and Contract Services Acts. I also hope I have convinced at least a few that the Policy has nearly put America's entrepreneurial and risk-taking individuals out of (going into) business and has particularly disadvantaged low-income earners who wish to get ahead in society by venturing their own ideas. Remedies suggested by others were also discussed, particularly flat-rate taxation.

Added to this, I suggest the elimination of any labor law which directly (or indirectly) noncompetitively sets labor's cost, and, by this reform, reduce the corporate manager's propensity to automate anything that moves. While providing significant near-term consumer price benefits, the capital-for-labor substitution motivated by the wash-out of labor's cost in competitive pricing unfortunately also causes loss of labor's flexibility to rapidly and efficiently adapt production operations to new technological opportunities as they may unpredictably arise, and leaves our domestic products "sitting ducks" for foreign imports.

I haven't meant to imply, however, that all production capitalization is not a good thing,only that general purpose production capital to perform operations which are not possible by labor at any cost ought to be preferred, such as high-speed, general-purpose, computer-controlled production processes. The new "robotics" seems to fit this category as well.

Overall, public policies must foster Schumpeter's "creative destruction," if capitalist enterprise is to survive, and, in the long run, our liberties. But the invisible National Innovation Policy fosters exactly the opposite. It fosters protection of current capital from entrepreneurial challenge, not "creative destruction" of capital.

Also key to bringing "creative destruction" back into our economy, and thus preserve our liberties in the long run, is a massive overhaul of R&D policies. I have attempted to show that civil and regulatory agencies have expediently adopted weapons R&D policy, a policy characterized by Government technical and product decisionsmaking implemented by special financial instruments which have been designed solely for the purpose of attracting industry to Federal monopsony. These instruments contain incentives so attractive that they will always drive Wall Street's financial instruments out of private capital markets. They must contain specially attractive incentives. Otherwise, an aerospace industry would not even exist, and our national security would be endangered.

DOD's special R&D policy works fine for Federal monopsony; that is, for national security and space science innovation markets, because Government has no choice but use taxpayers' money to finance an array of competitive innovations from which it must ultimately choose for its own operational purposes. It must sponsor what it consumes, acting as a single buyer. In its constitutional role of "providing for the common defense," Government's monopsony is entirely legitimate. It is authorized to start new innovations, and also responsible to finish those selected for operational inventory, purchase, and operate them.

But no civil or regulatory agency acts as a single buyer of some of the innovations which it was authorized to start. Thus, it logically follows that these agencies cannot use weapons R&D policy implemented by specially attractive financial instruments to govern civilian and regulatory innovative activities. Nevertheless, directed by Congress, all civil and regulatory agencies have expediently adopted weapons R&D policy, including the EPA. Here is where the split between authority to start and responsibility to finish makes a significant difference economically.

HERE IS WHAT IS NEEDED

Brand new civilian and regulatory innovation policies are badly needed. They must be designed to motivate important public goals to become private interest, without resort to Government's coercive power to force "what it thinks best" onto all the rest. This coercive approach simply won't work in America.

All that is needed are special "financial deals" for special statutorily created and nondefense innovation markets, and discard of all venture-capital financial instruments which are used to implement weapons R&D policy. These inappropriate financial instruments should be replaced by new ones to implement new civilian and regulatory innovation policies.

The issue of innovatively, efficiently, and effectively achieving important civilian capabilities--such as energy independence, and environmental social goals, such as EPA's--cannot center on should Government intervene in the free market economy, but rather on when and how it intervenes.

The when refers to Government's intervention into free market activities relative to design-progression. The how refers to the financial instrument which is used as a means for intervention. The combination of *when* and *how* should offer a "deal" to private venture capitalists, as compared to other opportunities, which motivates private investments in national goal-responsive innovations at the idea phase of design-progression--the innovation entry point affordable by entrepreneurs. And the financial instrument should implement a "one shot" governmental financial intervention at a public test position which had been previously financed by private capital. Government's financial intervention would amount to a fully discounted pay-back of all private capital spent and risked to bring the idea to a testable status, if the idea tested by a public laboratory shows technical promise of meeting national civilian and regulatory goals sometime in the future.

After its "one shot" intervention, Government should withdraw entirely from the remainder of the innovative process, let private capital finish the innovation, and let free market choices decide "whether it is indeed best for all the rest." Because private capital would have financed a new idea to a public test position, and public capital used only as a *post-facto* pay-back, obviously all the current debate about patent and data rights assignments would become academic, and the terribly high nonproductive costs incurred by Federal patent and contract lawyers would be substantially removed from our economy.

What it all comes to is this: Weapons R&D policy and its special implementing financial instruments cannot achieve a design-progression "one shot" intervention. It fosters intervention throughout the total innovative process, from the selection of ideas to inventory phase-out. Under weapons R&D policy, Government intervenes into the capitalist enterprise economy right at the beginning of a new weapons venture, and like the unwanted guest, it stays. This continuous intervention is legitimate for weapon and space system ventures, but illegitimate for all others.

CONCLUSION - MUNICIPAL WASTEWATER TREATMENT

In conclusion, I would like to describe a study we recently performed for the Department of Commerce. Its ETIP program manager asked us to examine EPA's municipal wastewater treatment innovation marketplace from the political economy viewpoints which I have described. I was given an excellent industry structure report to review, analyze, and comment on. Arthur D. Little Corporation (ADL) had delivered the report to the EPA. It had been prepared under the direction of Dr. Terry Rothermal who, I understand, is also a speaker at this session, and I wish to take this opportunity to complement him and his staff for the report's professionalism.

ADL's 1978 report described a situation of innovative stasis and, in its terms, "profitless prosperity," with industry losing interest in the growing municipal wastewater treatment market, a declining industry interest even though billions of Federal Construction Grants are available and include an additional 10 percent if EPA judges proposed municipal plant designs as truly "innovative."

Here I found venture capital federally distributed by means of weapons R&D policy financial instruments--grants, cooperative agreements, and R&D contracts. (I should parenthetically add that cooperative agreements, which involve cost-sharing of taypayers' money with the firm's first money are financial arrangements practiced more by civil agencies than by DOD. Such joint financial arrangements raise the interesting question as to who, precisely, is responsible for outcomes--the agencies' managers or the companies' managers? The answer is equally interesting--neither is responsible.)

Essentially, what I found by reviewing ADL's report was that one financial instrument--Congress' Construction Grants Program--splits authority to purchase--the municipality--from responsibility to decide precisely what is to be purchased--EPA. This purchasing authority/responsibility split promoted by the Grants Program cannot be found in weapons innovation markets because military organizations are totally responsible for the ultimate consequences of their authorities to select initial conceptual weapon designs, explore them, and eventually make an investment choice for inventory.

But for non-Federal public consumer markets, such as municipalities, the disconnect between initial authority and ultimate responsibility totally confuses the allocation of product responsibility as we have recently witnessed in the Three Mile Island nuclear accident; plus, of course, this further lengthens delays in municipal purchasing authority, increases chances of innovative firms losing their proprietary designs to competitors, and collectivizes technologies and designs to a national level through EPA's legislated decisionmaking technical role.

While "cloning" America's society and socializing its economy is what we should expect from weapons R&D policy--and we have no choice but accept this outcome--extending weapons R&D policy into almost all major segments of the nation's Gross National Product (GNP) is entirely unacceptable. Very few, I believe, would want a cloned society and socialized economy as an outcome of civil and regulatory agency innovation policies.

With EPA statutorily directed to determine "innovativeness," an interesting situation develops. It is wise for equipment suppliers to spend scarce resources to find what EPA's laboratories have already sponsored, or are currently working on, and then feed their approaches back to the EPA laboratories that are assigned an innovativeness-evaluating role, rather than spend scarce private resources to create and propose innovative designs which may actually compete with evaluating laboratories past and current directions, a hidden competitive situation which almost all defense suppliers are very familiar with.

The other key institutional problem I located while examining the report was a sequence of monopsonistic decisionmaking. As mentioned previously, monopsony describes a "single buyer" marketplace situation in the obscure language of our "dismal scientists"--our economists. It has the reverse meaning of monopoly--a single seller situation.

Again, DOD and the National Air and Space Administration (NASA) are our most obvious monopsonies. To briefly expand the point, Federal venture capital is absolutely required to supply these agencies monopsonistic innovation markets, for no private venture capital would fully develop, say, an MX missile, put it on the shelf, and hope the Air Force may some day purchase it. The same holds for a space shuttle.

This is why weapons R&D policy "clones" a society: An MX missile will provide as much national security for you as it will for me, and we will have no other choice, nor will the rest of the population. And, it should be clear that using weapons R&D policy to govern the venturing of new autos for example--a recent thrust to convert capitalist enterprise into collectivism and centralized economic planning--will give both you and me a single collectivized (and "cloned") auto choice in the future, which is the same as saying, no choice at all: Mr. Hobson's--"You can rent any horse you want as long as it's the one closest to the door," and Mr. Ford's--"You can buy any color auto you want as long as it's black" are apparently the architects of our U.S. R&D policy.

While reviewing the report's excellent description of innovative activities within the municipal wastewater treatment marketplace, I felt as though I were reviewing activities which lead to the introduction of the F-15 fighter into the Air Force's operational inventory, a program I happen to be quite familiar with. Only one wastewater plant within a municipality will be constructed and only one constructor award will be made. This marketplace situation describes a single buyer/multiple seller relationship much as the relationship which the Air Force established when it completed the production of a single F-15 fighter design and awarded a single contract to McDonnell Douglas Corporation to finally develop and produce it.

From the viewpoint of competitive constructors, the municipality acts also as a monopsonistic buyer of a long-term, perhaps 40- or 50-year, capitalized investment. And, as a single buyer, the municipality has enormous negotiating leverage over competitive constructors, as does DOD over all its weapon suppliers. Over 4,000 DOD procurement regulations attests to this, and if any in the audience have taken time to plow through 3,000 pages of DOD's procurement regulatory procedures, they understand fully what I mean by "enormous negotiating leverage."

With its centralized control over planning and, later, enormous negotiating leverage over competitive constructors, the municipality's source selection board will naturally tend to reduce risk by selecting already proven designs, and naturally auction constructors during competition to the lowest construction price. Neither motivation is conducive to encouraging risky, innovative equipments and processes.

Or an entirely different motivation may be involved, again as often found within DOD. It results in a reverse outcome. Municipalities may, with U.S. taxpayers paying almost all plant construction costs by means of Congress' Construction Grants Program, select "gold-plated" designs which result in overcapitalized and undermaintained plants; the latter expense, of course, paid totally from local tax bases, even though downstream localities benefit equally. DOD is often criticized for the same outcome. It, too, often capitalizes gold-plated and undermaintained weapons, an unfortunate outcome of all monopsonies unless great care is taken.

In either extreme--constructor auctioning or gold-plated designs--the winning constructor will reopen bids for equipments, select suppliers that propose old, low risk designs at the cheapest prices, and, with a fixed price contract, keep any marginal cost reductions gained from "bid-shopping" as an additional profit factor.

I concluded that the monopsonistic sequence, the municipality first, the award-winning constructor next, plus the legislated intervention of EPA into the technical decisionmaking process, absolutely precludes the introduction of innovative designs into municipal wastewater treatment markets.

And, indeed, A. D. Little had found a definite shift in innovative designs from municipalities--where they had appeared before the institution of the Construction GrantsProgram--to private firms where the purchaser of new innovative designs and the decider of what is to be purchased are, in fact, one and the same.

The purchasing companies' decisionmakers and the managers of firms which propose innovative designs both have similar interests--both understand that decision delays erode profit factors for both the purchasing firm's operation and the proposing firm's innovation. Their interests in efficient (i.e. quick) decisionmaking are in harmony, and the chances of losing proprietary designsto competitors are markedly reduced by eliminating their premature exposures during the open and public planning process.

I also suggested some institutional remedies to this disparaging situation,which I won't introduce and discuss at this time due to time limitations. I would be pleased to discuss them later with any who are interested. Conceptually at least, they show promise of remedying innovative stasis within non-Federal public consumer markets, such as municipalities. The report which contains these policy ideas is titled Alternate Approaches to National Technological Goals, April 1980, and is available from the Department of Commerce, Experimental Technology Incentives Program, Dr. Ted Schlie.

GOVERNMENT PATENT POLICY

Joseph P. Allen, Staff
Senate Judiciary Committee

After recent changes on the Hill it is hard to define exactly where Government patent legislation is at this particular time.

Therefore I will run through briefly the feelings of the Senate Judiciary Committee on the Government patent policy and describe some of the bills that are still pending before Congress when it reconvenes next week.

In late 1978, Senator Birch Bayh from Indiana along with Senator Robert Dole of Kansas introduced a bill called S-414 which would allow universities and small businesses to retain title to inventions they make while they are working for the Government.

The reason that Senator Bayh became involved in this is because of a situation at Purdue University where people were working under a Department of Energy grant and they invented what looked like a revolutionary new process for making gasohol out of corn stalks. That is something that Senator Bayh and most people in Congress are very interested in as a new domestic form of energy.

The problem has been that the present Government patent policies stipulate that when making an invention while working for the Government, the burden is on the inventor to justify why he or she should be allowed to own the invention -- regardless of whether the Federal agency involved is going to develop it or not.

These policies have been in effect for probably 30 years. Our office found about 22 different policies among the various agencies. Some agencies even have more than one policy. The basic presumption has always been that if there is any Federal money involved at all, the Government agency has a right to own the invention, and it is up to the contractor to go in and justify, on a case-by-case basis, why the agency should deviate from those provisions and allow the contractor to own the invention.

The upshot of this has been that the Government agencies now own about 30,000 different patents, covering the complete spectrum of Government research, which includes just about everything. The agencies are only able to license out about 4 percent of those patents to private industry. This is a very low percentage, compared to the universities, which at this time are licensing out about 33 percent of their inventions. I do not have a figure for private industry, but I think that by anyone's figures, Government licensing is rarely successful. Our office became very concerned with growing evidence of sagging American innovation and productivity, which is further harmed by the present ineffective Government patent policies.

This policy was hurting not only the inventors who were being frustrated by Government insistence on ownership of inventions that the agencies were not going to develop, but the policy was also hurting the American public who pays billions and billions of tax dollars in research funds and who is not getting the appropriate and deserved returns. This has been a very ineffective way to provide new products for the American consumer.

We found that the Departments of Energy and of Health and Human Services, (what used to be Health, Education & Welfare) would frequently take 2 to 2-1/2 years just to work on this case-by-case review to decide whether or not the contractor could own the patent. That did not mean that after 2-1/2 years the inventor could own it; that would just be the time it took to obtain a decision.

We have also been concerned that, according to the figures supplied by the Office of Management and Budget, only 3.4 percent of Government contracts were going to small businesses. In view of the number of studies that have been done showing that small businesses have been the largest creator of new jobs in the country and have a very distinguished record of creating new innovation, we were concerned that small businesses were really being shortchanged.

Our office talked with a number of presidents of small businesses who had testified before the Committee. While there were a number of problems with small businesses in innovation -- as you have been discussing here at this conference -- one particular problem was that the small innovative company simply cannot take a risk on losing an important patent to the Government.

Many of these small companies are competing against much larger corporations. Their willingness to take a risk that the big companies won't take, and their technological background, is what keeps them in the market. And if the Government takes away one of these important patents, or even more dangerously, forces the small business to make its technical data available to other Government contractors, the success of the company can be imperiled.

For many small businesses that was a deadly threat to their technology, and they just could not accept a Government contract. On the other hand, there are some small businesses that live for Government contracts and for whom marketing and developing inventions are not that important. Such companies are not affected by these policies.

Thus a number of small companies will take Government contracts regardless of the patent rights, whereas many high technology companies are shying away from doing Government business. This becomes a double-edged sword for the small businesses because they are also afraid to become involved with universities' research programs.

Universities have research facilities that a lot of small businesses could match up with to great advantage, but the catch-22 is that almost all universities are receiving some Federal money, and as long as there is

Federal money involved -- the Government could come in and say: "This contract was made in part with our money; we have the right to own the invention."

So, in order to cut through this whole bureaucratic nightmare, Senator Bayh and Senator Dole put in legislation that would allow universities and small businesses to own the patents to the inventions they are making, unless the Federal agency can justify some extraordinary circumstances by which it should be allowed to own the invention.

In other words, this legislation is completely changing the presumption of the present policies. The burden will be put on the agencies to say "This is an unusual circumstance and we should be allowed to own the invention. The Administration and the House of Representatives back this bill, and it has also passed the Senate by a vote of 91 to 4.

The issue has always been a very emotional one. Admiral Rickover in the Department of Energy, for one, and Senator Long have been debating this issue for about 30 years now. The rejoiner has always been: "Whatever the Government pays for, the Government should own," which became a popular catch phrase that did not really adequately express what was going on. We had a three-day running verbal battle with Russell Long on the Senate floor, but finally the Senate did pass the bill.

The Administration decided that it wanted to go a slightly different route. They wanted to give universities and small businesses title but then said they would allow medium-sized companies and larger companies to get an exclusive field-of-use license rather than title.

At this time we do not know what the reaction of the Senate is going to be. I think there are a number of bureaucratic problems about how such a proposal would actually work. In a number of ways it might create an additional paperwork burden. But even more disturbing is that according to the Administration bill, regardless of the item about license, the contracting or funding agency can still own the invention and procure title as long as the invention is "related to the agency's mission" or is "in the public interest."

This presents a loophole that is invitingly large and may in effect include virtually anything made under Government contract because everything is going to be related to the mission of the agency or the public interest if it is worth anything at all.

Senator Bayh tried to get a bill passed before the Senate recessed before the election. Unfortunately, the House was not able to work on their bill so now we have a situation where they are coming back after the recess to try and pass this bill, and the Senate and the House would probably have a conference to work out the differences between the two bills.

Now that there has been a changeover in the Senate, it is unclear whether this bill is going to be brought up at all. After the recess, the House and Senate will have to pass the appropriation bills, and since there is a new Administration and a new Senate, it is very likely that they will just pass a continuing resolution on the Government funding and then recess.

Frankly, our office is very concerned that we might not be able to solve this problem, not even part of the problem, during this session of Congress. I think the votes are there, but it is mainly a question now of timing--whether or not the Congress is going to stay in session long enough. Obviously Congress is not coming back just to decide Government patent policy, but at least I think the groundwork has been laid and the Congress is sensitive to this problem.

This whole area of innovation and technology is going to be something that the Congress is going to be addressing for many years to come. It is just too serious a question to back away from.

That, basically, is what our office has been doing, and I think that regardless of whether it is a Republican-controlled Senate or a Democratic Senate, there is bipartisan support on doing something to improve American innovation and productivity. Especially there is very strong evidence that the present patent policies simply are not performing adequately or up to the standards required for developing modern technology.

Question (Dr. Reznek): Was there any discussion of some form of mandatory licensing to the inventor if the Federal Government's cost of research is repaid? In other words, when you enter a contract, the agreement is that you will have exclusive rights to the invention so long as the cost of the Federal subsidy of the research project is repaid. Was that discussed?

Response (Mr. Allen): Under our bill the inventor, if it is a small business or university, would own the invention. This does include a recruitment provision which says that if you make more than $70,000 in licensing the invention in one year, you would repay to the Government 15 percent of the additional income. This is a year-by-year formula. The inventor would have to make $70,000 each year; and then you trigger the figure, and if you would make more than $1 million in the manufacturing of the invention, you would pay up to a maximum of 5 percent above that; there are also a number of things in the Act about how important this patent really is.

So the inventor would own the patent under S-414. There would be a pretty serious burden of evidence the Government would have to meet before it could take the patent away from the inventor.

Industrial Research and Development Planning and Investment Strategy

Chairman:
Roy N. Gamse
Deputy Assistant Administrator
Office of Planning and Evaluation
U.S. Environmental Protection Agency

Panelists:
Alfred G. Zeigler
Terry W. Rothermel, Ph.D.
Tobias Anthony
Ian F. T. Kennedy

INTRODUCTORY REMARKS

Roy N. Gamse, Deputy Assistant Administrator
Office of Planning and Evaluation
U.S. Environmental Protection Agency

I am Roy Gamse, Deputy Assistant Administrator for Planning and Evaluation at the U.S. Environmental Protection Agency (EPA), and I am glad to chair this panel on Industrial Research and Development Planning and Investment Strategy.

EPA has a strong interest in sponsoring development of better and cheaper solutions to today's environmental problems. If you think about the problems of regulating not just this year and next year, but on into the future, you reach the conclusion that we need to develop a better, more efficient, less costly, and more effective pollution control technology.

We also realize that many of our regulatory programs are set up in a way that may not always encourage the kinds of innovation technologies that we will have to achieve in order to keep pace with the growing economy. It is very important to see this from the perspective of the firm that is developing pollution control technologies or is faced with pollution control problems and may or may not have an incentive to find a better, cheaper, or more effective solution to the problem.

I hope that in this panel we can really put ourselves into the shoes of the people who face decisions, who plan out the Research and Development (R&D), and who decide whether to go ahead with the project or not. Our presentation should be able to provide some personal perspective on how those decisions are made by the firms that have to make them.

I am anxious to hear our panel members talk about the business motivation to do R&D in this area; how recent environmental laws and regulations have affected the market for pollution control technology; how we can design those laws to have a more favorable effect; the market problems that the pollution control industry has faced; and how industry and Government can work better together in this area to provide the right kinds of incentive.

FORM FOR EPA CONFERENCE MANUSCRIPTS

Please read all attached instructions before you begin typing

TITLE (After first page, use this line for manuscript)

INDUSTRIAL RESEARCH & DEVELOPMENT PLANNING AND INVESTMENT STRATEGY

Alfred G. Zeigler, Manager - Industrial Group
Envirex, A Rexnord Company

Manuscript
Second line

Motivation for Industrial Research & Development is the profit potential represented by the anticipated result.

Almost all industrial activity is in development; there is limited, recognizable profit potential in research.

Planning is predicted on identifying needs not satisfactorily served by current technology. Such needs are evaluated with regard to capabilities available to the company and for compatibility with current or planned activity.

When an opportunity is recognized, it is thoroughly evaluated; and, if profit potential exists, a business plan is developed to define that profit potential and to establish investment requirements and the cash flow involved in realizing that profit.

All areas of operation must be included in planning and carrying out a successful Research & Development program. It is essential that each operation be committed to the program and accept responsibility and accountability for its portion of the program. Management must be committed to plans for the company which involve utilization and promotion of the development, and such commitment must include financial support of the program. The groups responsible for the technology, marketing, sales, and manufacturing/production must be fully committed on the basis of the specific business plan which needs to define their participation in detail.

Periodic review of the overall company program and the individual projects comprising the program is essential. Such periodic review permits effective adjustment of the program to react to change.

The key to effective Research & Development is detailed planning with well-defined areas of accountability and effective administration of such detailed plans to obtain results on time and on budget.

The preceding description of Industrial Research & Development planning strategy implies that the single, overriding consideration is profit. This is a hard, realistic fact; please recognize (and acknowledge) that this is good.

It is important that we acknowledge openly that the primary purpose of business is to serve society. And to do that over a long period of time, business must operate profitably.

When it is the public perception that business is not recognizing and

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reacting to the legitimate demands of the public, then the public demands governmental action or regulation to remedy these facts.

The mass media are crucial in shaping the public perception and, unfortunately, portions of the mass media are susceptible to sensationalism. EEO, OSHA, ERISA, and possibly the EPA are examples of governmental regulation demanded by the public because business failed to recognize and react to legitimate demands of the public.

Unfortunately, Government usually tries to fix everything for everyone all at once. Regulators often tried to write down to the most minute detail, creating an administrative nightmare. Such an approach can be inefficient and costly in time and resources.

I would like to quote from an address before the Machinery and Allied Products Institute by Robert V. Krikorian, Vice-Chairman and Chief Executive Officer of Rexnord, entitled "The Bridge to Public Trust."

> "Each of us must recognize that all costs are ultimately passed on to the consumer and the taxpayer. The costs of material, labor, energy, product liability, and every variety of tax paid by business is inevitably shared with the consumer, our customer. If he decides not to pay these higher costs, then, of course, the business along with jobs will disappear."

It is recognition of these facts and acceptance of this philosophy which must be used as a base for Industrial Research & Development planning and investment strategy.

When the Industrial Research & Development will result in a recognizable benefit to the company with a return commensurate with the risk involved, the company will invest its resources; when such is not the case, funding must be obtained from another source.

When funding or support is available from a source other than company resources, the program must be evaluated to measure the probable return with the risk involved in order to justify commitment of the company's resources.

This discussion is limited to company-funded Research & Development in the Environmental Technology Industry.

In industrial activity there is no "free lunch." If a company is to survive, it must produce a profit which is acceptable and satisfactory to its owners -- its stockholders. All of its costs, including Research & Development, are ultimately incorporated in the cost of its products and services.

The selling price of its products and services is dependent upon these costs, and if these costs are excessive -- resulting in a noncompetitive selling price for its products and services -- the company will ultimately fail.

I have talked about company-funded Development in the Environmental Technology Industry. There are other funding procedures (public grants or publicly funded programs).

There may be well-recognized needs which, for one reason or another, do not define desirable projects from the standpoint of justifying the expenditure of corporate funds. Some of the reasons are implicit in the preceding discussion; the major factor is again profit. If a program has only a remote chance of profitability for the corporation, even if the Research or Development efforts are successful, the corporation cannot justify funding the program. However, funding by a potential user or funding by a Governmental agency, Federal, State or local, may make this a desirable Research & Development project. Many programs are so funded and are mutually beneficial to the agency providing the funding and the company doing the Research & Development.

With a very few exceptions, technology in the environmental waste area is well developed. (I hesitate to describe it as mature since it may imply the technological advances have peaked and are flat or on the decline.) The few areas that are ripe for Research and/or Development are sophisticated; the expense associated with the program is excessive; the possibility of a development profitable to the funding agency is remote. With these constraints, these areas will be developed only when the need becomes great enough to inspire funding by a governmental agency; or, alternately, a private corporation dealing in high risk ventures, structured to limit the risk exposure to a single effort or a few such single efforts, may handle the Research & Development program if the potential return, in the event of a successful program, is great enough to justify the high risk involved.

I have attempted to keep this discussion general and shy away from specific examples. As such it may seem unduly philosophical, but such philosophy is the very basis for the planning and strategies involved.

THE 1980 CLIMATE FOR INDUSTRIAL INVESTMENT AND R&D IN POLLUTION CONTROL TECHNOLOGIES

Terry W. Rothermel, Senior Staff Consultant
Arthur D. Little, Inc.

It is, as it has always been in a competitive economy, that industrial research in pollution control technologies or any other field must compete with alternative investment opportunities. In 1980, this means competing with energy as a target for research and business ventures. In 1980, commitments to pollution control research, in particular, need to be justified on long-term market conditions that differ from those that led to unattractive profitability for environmental businesses in the late 1970's.

The recent withdrawals of major participants from environmental markets confirm that this industry's Number One fidelity--like that of any industry--is to profit. It is not surprising, in hindsight, that those that were quick to pursue perceived environmental opportunities have been among the first to retreat from the "profitless prosperities" among environmental markets. Assuredly, more firms will remain to serve pollution control needs than those that leave to pursue more attractive opportunities. But it is not at all certain that their perseverance will be rewarded.

There really can be no question that there are--and will continue to be--needs for new technology to control both existing and emerging pollution problems. The means by which these needs are to be met, however, remain in doubt. An outline of several institutional aspects of this "R&D gap" was a part of our 1978 report to EPA on the pollution control industry.

First, the leading firms in pollution control businesses are not among the largest firms in American Industry. There are very few for which overall corporate sales total a billion dollars or more. In the cases of those billion-dollar firms, their pollution control revenues typically represent less than 10% or even 5% of their corporate portfolio.

The implications of the lack of size among the leadership of the pollution control industry are ones of financial resources and corporate commitments to technological innovation which are to be expected from them. Compare their size and resources to those of the firms which can be expected to be technical leaders in the energy, aerospace, or natural resources industries.

In addition, the companies which were in the sewage treatment, dust collection, and solid waste businesses before the environmental era do not have their roots (with apologies to a few exceptions) in research and development. Their markets did not require it before the 1960's and 1970's. Most pollution control efforts in the last two decades have been directed towards broadening the application of the best existing technological practice. And their profitability has not been sufficient to encourage these companies to increase their R&D commitments.

Other billion-dollar corporations--and there have been many--which have tried to enter environmental markets on a technological basis have not been successful in achieving the leadership that they are accustomed to in other businesses. One of the reasons for their failure has been the importance of marketing in these businesses -- a subject that I will cover in greater detail later this afternoon. Another side of the coin is that these billion-dollar corporations are among those firms which have had to struggle themselves with the increased costs of pollution control for their main businesses. The technical motivations of companies wishing to minimize pollution control expenditures are not nearly as powerful as profit-seeking motives. Indeed, I am sorry to report from our client experience that the internal customers for pollution control suppliers in these diversified corporations are among the most difficult ones to sell. There are many reasons for that, but certainly one of them is that of mixed corporate feelings towards pollution control progress.

At the same time, Federal R&D budgets in support of environmental solutions have not grown apace with the regulations. The allure of energy-related research has also diverted some of these budgets away from strictly environmental targets. That is not to say that energy-related research is inappropriate for EPA because the motives--this time in the *public* sector--of energy-focused agencies must be questioned.

We have also noted an increasing presence of foreign technology in the U.S. marketplace. Foreign suppliers are becoming *more* interested, it seems, in the U.S. market at a time when the interests of our domestic industry are waning. At a recent international industry conference, for example, less than 25 of 2,500 preregistrants were from the United States. There does seem to be a difference in motivation for some of the foreign suppliers. There seems to be more of an interest in a business *per se* and less in its short-term profits. This relates to a growing concern with the short-term decision framework of American Industry, generally. To a degree that U.S. corporations are emphasizing short-term results over long-term positions, the role of R&D is necessarily impaired.

One of the realities of R&D management is the time required to develop, prove, and commercialize a new product. In the environmental arena, this development time is certainly longer than the "double time" pace of regulatory initiatives and mid-course corrections. As regulatory efforts move from a "catch-up" phase to "steady state," maybe new technologies will have a better chance to be developed--not in the context of new regulations, but more in the context of improved controls over time.

Another reality of technological innovation is that the best economics for a new approach must await the benefits of experience before enjoying the greatest competitive edge over established techniques. This is the wisdom of the newer incentives for innovative technology in the municipal sewage treatment grants program: the willingness to fund new technology even though its expected costs may be somewhat higher than traditional alternatives. This is the wisdom in an industrial pollution control policy that would allow plants to defer compliance in cases where new technologies are to be employed. The learning curve of innovation cannot be denied any more in regulation than in business. The economic and environmental rewards of new technology must be expected to be preceded by greater-than-anticipated amounts of time, experience, and investment.

In closing, I believe that there is a need for joint or cooperative R&D efforts between the private and public sectors, also within the pollution control industry. Otherwise, the institutional constraints make me pessimistic about the future pace of technological innovation in pollution control. Such joint efforts will assist in charting the record of technological innovations in future sessions of this conference. Joint efforts will help protect needed long-term research against economic and funding cycles that affect both the private and public sectors.

I am aware that such joint research efforts can be suspect for antitrust or anticompetitive reasons. On the other hand, I believe it can be shown that such research would improve the quality of competition in the pollution control industry as well as its pace of technological development. In this case, then, the competitive benefits of joint research would exceed the associated competitive risks.

INDUSTRIAL RESEARCH AND DEVELOPMENT PLANNING AND INVESTMENT STRATEGY

Tobias Anthony, Director
Business Development and Washington Affairs
Research-Cottrell, Inc.

I am privileged to be here today to discuss R&D planning and investment strategy in the environmental industry. But perhaps a title that would be more accurate would be something like "Crisis Hits the Pollution Control Industry," for that is how the leaders in our industry view its condition. We have seen ourselves transformed from one of the healthiest industries in this country to one with financial difficulties of major proportions. Now, I am not here to rattle off a litany of lamentations, but, rather, I hope to be instructive and constructive, explain how we came to this point, and where I believe events are taking us.

Research-Cottrell's history is the history of the environmental movement. For more than 70 years, we have borne witness to the essential forcing factors in the development of environmental policy and of control strategies. We witnessed a slow evolutionary change in the nature of these factors gradually accelerating, asymptotically, into the crisis years of the 1970's and forcing us to change our investment strategies.

While we are involved in almost every aspect of environmental control and will continue to be in the future, for the sake of clarity I would like to trace our history in the stationary source, air pollution control sector. That is the first sector where technology development and investment strategies became so sigificant to the understanding of how and why our strategies changed. Furthermore, lessons learned there are now appropriate for projecting institutional and financial relationships into the 1980's and 1990's.

There are four factors which govern investment strategy decisions in pollution control. While the factors have not changed over the past 70 years, their character certainly has.

1. Congressional goals for environmental quality.
2. Legislation and regulations designed to meet those goals.
3. Enforcement and, therefore, the interplay among Government agencies, pollution sources, and suppliers of control technology.
4. The technical and financial resources needed to satisfy Congress' goals according to its prescribed schedule.

Prior to the Clean Air Act of 1970, Government perceived itself as a gentle, but forceful persuader. Goals were modest, so all Government, with State Government leading the way, sought to persuade pollution sources to clean up in order to improve ambient conditions. Markets were dominated by the usual customer-supplier relationships; emission limits were modest; compliance was affordable and well within the technical state of the art. Particulate control was the essential target, and electrostatic precipitation was the primary control technology which remained unchanged for decades.

Emission control was effectuated on a case-by-case basis.

Consequently, the market was more or less predictable. More than 90 percent of Research-Cottrell's R&D funding came from internal financial sources. It was applied to product improvement, as well as to fundamental research -- for example, pulse energization and SO_2 scrubber technology. We spent some 10 to 15 million dollars this way prior to 1970 at a rate of 1 to 1.5 percent of annual sales, which was in line with other capital goods suppliers in other industries.

The public's impatience with the pace of achieving environmental quality led Congress to pass the Clean Air Act of 1970. The Act called for two sharp changes. It called for sharper limits on particulate emissions from boilers, which pushed the limits of the state-of-the-art of electrostatic precipitation, and for the first time it called for postcombustion cleanup of sulfur dioxide. A more subtle and fundamental change also occurred, we were to find out: The Act took authority away from the States and gave it to a new agency, the U. S. Environmental Protection Agency (EPA). Not for some three to five years would we realize the dramatic impact of these factors on our industry.

Electrostatic precipitators had to be redesigned on a crash basis. Size modifications, coal characteristics, flue gas temperatures, and material would now be more sensitive to our design criteria. New foreign technology was introduced and fabric filter applications would be attempted. Since Research-Cottrell was the dominant supplier, we bore the heaviest financial burden, causing us to lose $3 million in profits in 1974. Not only would particulate control never be as profitable as it was, largely due to the influx of competition, but we would experience the effects of regulations on our profitability. Investment strategies changed from that point on.

Sulfur dioxide control presented an even more far-reaching influence on our decisions. We had been developing a limestone scrubber for sulfur dioxide control with support from the EPA. No commercial technology was available, yet emission limits were established based on small-scale pilot work. Thus sulfur dioxide control looked like the next opportunity. But confrontations between the EPA and pollution sources over designating sulfur dioxide as a criteria pollutant created a new climate of unpredictability that served to disrupt traditional customer-supplier relationships so necessary for long-range planning of investment decisions.

The more cases pollution control sources lost, the more authority was consolidated in EPA. Still, enforcement became unpredictable, and our industry hesitated to make the R&D investments needed to meet the Act's timetable. Meanwhile, new threats developed. EPA began funding R&D to demonstrate new scrubber technologies, thereby allowing a host of competitors to enter the field. Enforcement became erratic, and pollution sources complained that control technologies were no longer affordable. Traditional investment judgment factors gave way to new ones: regulations, legislated technologies, litigations, and edicts. By the mid-1970's, we began to realize what is meant by "legislated markets".

The Clean Air Act of 1977 completed the transition. The Federal Government would dominate the important decisionmaking criteria. New policies would be introduced to create more uncertainty, e.g.,emission offsets, best available control technology, prevention of significant deterioration (PDS), PSD permitting, and four-year review of emission limits. No longer would traditional criteria be relevant -- such as, power demand forecasts, capital spending plans by customer industries, and application of the most cost-effective technology to specific sites. We would wait and watch for the next regulation or the next policy to run its course, be this to control trading, banking of emissions, etc.

Under these conditions of uncertainty it was obvious that the Federal Government would have to fund development of new technologies. Let me be specific on this point. It takes a company like Research-Cottrell some 3 to 5 years to develop a technology to the point of demonstration and some 3 to 5 years for payback during the commercialization phase. Because emission limits can change every 4 years, (or sooner, if a new threat is measured), and because EPA can put competitors into business, a current technology is almost guaranteed to become obsolete and the expected return on investment frustrated. Thus, if EPA pays for development, the period of financial risk exposure is cut in half. By 1979, fully half of our investment in R&D was funded by the Federal Government.

That is not to say that the payback period is free from uncertainty. We are confused over the time anticipated to site power plants and to install our equipment. How long are permitting periods expected to be? Which sites will be allowed to convert to coal? How long will litigation take? Since suppliers must retain a work force during periods of delay, costs are increased and, in a competitive market, profits are squeezed. The final result has been that several large suppliers in our industry are in unprofitable positions and are directing growth plans toward opportunities outside the environmental markets.

I must emphasize that up to this point we have discussed control of only two pollutants, particulates and sulfur dioxide. We should remember that a plethora of other laws was also passed in the 1970's. RCRA, TSCA, the Clean Water Act,and the Safe Drinking Water Act,which are designed to control hundreds and perhaps thousands of chemicals. Congress has imposed an imponderable burden on EPA, pollution sources, and suppliers of control technology to reverse the flow of these chemicals overnight and under emergency conditions. When the final rules are written to implement these Acts, it will be clear just how heavy this burden is.

What do the 1980's and 1990's hold in store for us all? The EPA has more than a hundred regulations listed in its agenda designed to control the flow of polluting chemicals. The regulations are aimed at hundreds of processes in tens of industries and in untold numbers of municipalities. Each chemical is designated a threat as important as the two we have described. There continues controversy over these designations, so we can be assured that the burdens and uncertainties of the 1970's will pale by comparison to what is in store when those rules are finalized in the 1980's and 1990's.

No estimate of the investment that will be needed is yet valid. But preliminary estimates are beginning to reveal that this "game plan" could command financial resources unavailable in the private sector.

Consider for example, the following projections: The Council on Environmental Quality (CEQ) estimates that abatement capital and operating costs resulting only from legislation for all purposes and incurred by all sources both public and private amounted to $27 billion in 1978 and could reach $64 billion by 1987. These are constant dollars corrected for inflation, and still they reflect a growth of 137 percent. The Gross National Product (GNP) meanwhile, in constant dollars is expected to grow only one third as fast at 43 percent. Thus environmental control in the next two decades will demand an ever increasing share of the nation's output and financial resources according to the Council on Environmental Quality (CEQ).

Studies conducted by Amitai Etzone and Nestor Terlickyj indicate that such a rate of growth on top of the growth of other quality-of-life and reindustrialization needs could not be financed over the next five years at least. Assuming this to be so and assuming delays caused by uncertainty resulting from existing laws and regulations, it seems likely that meeting Congress' goals and schedule will be frustrated and that we will have to stretch out the various programs.

If Congress persists in pursuing the current plan on schedule and if the private sector hesitates to respond, logic would indicate we could be heading toward the establishment of another Government-industry complex. One day in the future we might witness the reconfiguration of EPA's mandate fashioned along the lines of the National Aeronautics and Space Administration (NASA) or even the Department of Defense (DOD). Since EPA has been forced to assume technology development, operational compliance, and siting decisions, the only authorities left are buying, owning, and managing the capital stock.

Today's fantasies have a way of becoming tomorrow's realities, so we can fantasize a little. I mentioned that CEQ estimated the total bill for legislated compliance with pollution control would be $64 billion in 1987. Since this figure is calculated in 1978 dollars, the figures could easily be $120 billion in 1987 dollars, which is close to what DOD's budget might be. Even if we added another $10 billion for increasing the staff and facilities at EPA, we are not talking about an unthinkable budget in Federal terms. It is not inconceivable for a future Congress to mandate such a superagency or department. Is this what we want?

Or should we as a Nation pursue programs involving private sector participation as currently configured? If so, the Congress will have to prioritize and even limit its goals. These goals must be long range if both pollution sources and suppliers are to meet the targets. We must have fewer, simpler, less punitive regulations which remain in effect for a decade or so, in order to permit resourceful planning and to unite us in timely execution of these programs.

Finally, we must define the share of the GNP that will be available in view of the demands on resources made by other social, energy, and reindustrialization needs. These factors, when applied in a forum of concensus and

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dedicated resolve, could produce successful policies.

If such policies could be accomplished, I have no question that the private sector could provide the technology and finances needed to achieve new environmental goals. Truly, the future condition of our environment and our economy rests on those choices.

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GOVERNMENT, INDUSTRY AND THE INNOVATION PROCESS IN THE ENVIRONMENTAL TECHNOLOGY INDUSTRY

Ian F. T. Kennedy, President
HSA Reactors Limited

I will begin my presentation today by focusing on my perception of Government's problems in creating and sustaining a climate conducive to new and innovative technologies for the water pollution field. I will then focus on those planning and procedural elements which, from HSA's experience, would promote such innovation. Finally, I will examine some of the elements common to high technology companies by examples derived from HSA's experience in developing innovative compliance technology for treatment of the complex metal and cyanide effluents of the Metal Finishing Industry.

Industrial research and development planning and investment strategies, the cornerstones of technological innovation, are responsive to MARKET goals and opportunities. Government is responsive to SOCIETAL goals and national welfare. In the absence of an obvious coincidence of these goals and priorities, the existing adversary relationship which characterizes the current implementation of EPA water pollution control regulations, is inevitable. In particular, since there is NO STRONG MARKET INCENTIVE for pollution control research and innovation there is no way, except through active Government participation, that these societal goals can be substituted for those mandated by the marketplace. The methodology of Government participation is equally of key importance.

Industry currently perceives pollution control as an undesirable EXPENSE. If this perception could be altered to one of INVESTMENT THROUGH complementary Government - industry interaction, combined with a redesign of the various fiscal and legislative packages in order to support and reward the development and installation of innovative compliance technologies, much of the current conflicts would disappear.

The principal role of Government in the innovation process is to foster the climate for the creation of technology in a manner which marries the realities of Federal policy development with our collective knowledge of the innovation process and the needs and peculiarities of specific industries.

A possible methodology for significantly improving the innovation climate in water pollution control technology, and for promoting industrys' active participation in both its process and in the utilization of the resulting innovative products, could be through the formation of a National Task Force on Cooperative Pollution Control Technologies within whose broad framework would be specific Industrial Segment Task Forces.

This National Task Force, reporting to the EPA, would be staffed jointly by Government, industry, and academic representatives. The Industrial Segment Task Forces reporting to, and augmenting, the National Task Force would be staffed similarly, except that the industry representatives would, in each instance, be industry specific.

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The overall procedural elements of these Task Forces would be: 1) The identification by industrial segment of pollution problems and opportunities; 2) The identification and analysis, in collaboration with industry, of potential technological solutions and of probable impacts--technological, economic, industrial and social; 3) The execution of research, development, pilot demonstrations, and technology transfer tasks by Government, universities, cooperating industries, and selected industry R&D support capabilities; 4) The monitoring and evaluation of the Task Forces' processes and activities; 5) The recommendation to Government of viable "market pull" strategies to encourage both creation and use of the appropriate compliance technologies through Government procurement, tax incentives, grants, contracts, loans, manipulation of the market structures, and perhaps provision of capital to new venture companies; and 6) The orderly termination and phase-out of Federal invovlement and the technology transfer of the results of this innovation process to the commercial marketplace.

This suggested approach would, I believe, result in an atmosphere of cooperation rather than confrontation. Indeed, some of the elements of this approach are currently utilized by the Environmental Protection Service (EPS) in Canada. In this respect HSA has been participating with the Gold Mill Processors Working Group in demonstrating, at pilot-scale, the application of its electrochemical technology to the Gold Mills' metal and cyanide effluent problems.

Governments seek to spread economic benefits, the private firms to capture them. In this process the time element is important. Government support of R&D activities should be available on a sufficiently long-run and predictable basis that it encourages new and sustained activity. More specifically, R&D support should be available for both the initial startup of R&D activity as well as for the continuing R&D activity that is necessary to maintain the relevance of that original effort. It should not, however, be available for commercialization.

I would like to turn now to the specifics of new innovation, recognizing that the innovative technical solutions to appropriate pollution control compliance technologies, like the problems, are not simple but rather individually and collectively complex.

Before hurrying down the innovation road, however, a note of caution should be sounded. Innovation, to many, has become an article of faith, not just a desire of nations and corporations, but rather a necessary condition for survival and growth. Like many a demigod which man has created, innovation makes for the true believer Messianic prophesies of "renewal and life!" Regardless of your degree of conversion, I am sure you will agree that innovation, whether it is "new" or "imitative," is a complex process--difficult to foster, control, or describe, particularly with regard to those essential elements which will ensure its success. Indeed, innovation is impossible to predict, particularly since it is synonymous with dynamic change.

HSA is an entrepreneurial enterprise, incorporated in Canada in 1975, to research, develop, manufacture, and market products and services expected to emanate from "discoveries in electrochemical reactor technology" made by senior researchers at the Royal College of Chemistry, Imperial College, London, England.

This statement reveals some basic elements:

- HSA is entrepreneurial - a "sunrise"-type enterprise
- HSA is foreign - Canadian
- The "idea" was discovered in another country - England
- The idea has a university research basis which required a technology transfer between a university environment and an industrial environment
- The company has survived 5 years.

Reviewing these elements in sequence:

- HSA is entrepreneurial - a "sunrise"-type enterprise.

The "sunrise" type of corporation is one which is involved in innovative new products or activities which are expected to lead to the development of growing, new, and subsequently large businesses. These corporations are characterized by their competitive fluidity, horizontal organizational structures, capacity for risk-taking, and entrepreneurial and personal identification. Their basic investments in R&D are characterized by risk, significant front-end loading of investment moneys, delayed returns, and an appreciation of the time-value of money. In this last regard, entrepreneurs have often been described as those peculiar individuals who have a negative discount-rate philosophy - i.e., all present costs are zero, and all future profits are infinite.

What does a "sunrise" situation require? Perhaps the most basic element is the idea itself, then money, and for a successful continuance in a competitive business environment, a combination of science/technical, financial/administrative,and sales/marketing expertise. Most innovations don't succeed because one or more of those expertise prerequisites are missing - i.e., the inventor with no administrative and limited marketing skills, or the marketing wiz who "hits" a technical hitch and doesn't have the financial "staying power."

The concept of "sunrise and sunset" industries and technologies has at its foundation the explicit understanding of the intimate link between innovation and dynamic change in the product life cycle. This overall concept is being applied successfully in the national industrial strategies of several nations including Japan. It is essential for Government in planning for innovation in the pollution control field, or any other field, to actively encourage the sunrise-type industries.

Indeed, their importance has been highlighted in numerous studies, which consistently indicate that independent inventors and small technologically-based companies are responsible for a remarkable percentage (60+ percent) of the important inventions and innovations of this century. Yet, as recently indicated by Senator Orrin G. Hatch, these small and medium-size companies received only 3.5 percent of Federal Research Grants, of the $4.7 billion in Federal R&D expenditures made in the United States in 1978.

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The next two elements:

- HSA is foreign - Canadian.
- The "idea" was discovered in another country - England.

These elements indicate that "ideas" are international commodities. No one nation or corporation has a "corner" on the "idea market." HSA's example illustrates that since all major industrialized countries are now vitally concerned with innovation (its role, process, and effects on their national economic development), and since most of those countries started much earlier than either Canada or the United States and are therefore more sophisticated in their decisionmaking abilities, most major technological innovations will take place outside North America! So, if your innovation strategy does not include keeping an eye out for ideas elsewhere, your true opportunity will be severely limited.

The next element:

- The idea has a university research basis which required a technology transfer between a university environment and an industrial environment.

This element indicates that, while starting with a "high science" base, the translation of the idea to a commercial fact required the effective transfer of the idea to an industrial setting and then a buildup of all aspects of an organization necessary to assure commercialization.

HSA currently employs some 65 people, 60 percent of whom are professionals, including over 10 percent of the free world's PhD-level scientists in the discipline of electrochemistry. HSA's operations occupy some 47,000 square feet. Expenditures to date total some $6 million. A recent Financial Post survey of companies conducting research in Canada indicates HSA's 1980 expenditures of $4.5 million ranks it as 40th in Canada in terms of total annual Canadian research expenditures, ahead of such companies as Litton Systems and International Harvester.

Research and development work conducted by HSA since 1975 has confirmed the generic nature of the initial university discoveries and has broadened the commercial scope of potential applications to include applications in hydrometallurgy, energy, and organic synthesis, in addition to their pollution control opportunities.

However, the realities of the business world required, at the earliest possible instant, the focusing of our R&D strategies and the concentration, corporate-wide, of our efforts in commercializing one application in order to generate the cash flow to support the continuing research and development into the other areas of opportunity which will provide for the long-term growth and stability of the Company.

For HSA this meant concentrating our efforts into pollution control applications; and even more specifically, HSA perceived the metal and cyanide pollution problems of the metal finishing industry could represent

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an ideal fit between its evolving innovative technology and a real and pressing market need. HSA consulted with the EPA in early 1976 and began discussions with industrial representatives. HSA's analysis of the competitive technologies available in this industry, such as alkali-chlorination, ion exchange, evaporation, etc., was that these technologies tended towards being "sunset" technologies loosely adapted by equipment suppliers to the problem of the metal finishing industry. Furthermore, it appeared that the majority of R&D and industrial innovation in this field was directed towards gettting these technologies to cope adequately with these complex pollution problems. HSA's generic approach of electrochemistry was seen, at least internally, as an innovative approach capable of simply and elegantly solving these pollution problems with considerable capital and operating cost advantages to the industrial user. After industrial pilot testing in 1977, HSA undertook a Joint Demonstration Project with the EPA in late 1978. HSA systems for Cadmium, Copper, and Zinc are currently operating successfully under the terms of this Demonstration Project. The fact of pending regulation in that industry was a positive factor in the sense of a market drive.

The final element was:

- The company has survived 5 years.

The problems encountered by HSA during its first five years of operation typify the problems faced by most "sunrise," technologically oriented enterprises. These challenges center on: the development of the original idea to a commercial product; the acquisition and development of professional managers; and the attraction and measured utilization of capital.

In the instance of HSA, the Government of the Province of Ontario has played a fundamental supporting role by providing in excess of $6.5 million in long-term, provincially guaranteed, operating loans. These loans, combined with some $2.25 million in private equity, have provided the stable financial base for HSA during these initial stages of research and development.

HSA is now negotiating for senior financing which will ensure funding for commercialization of its reactor systems for the metal finishing industry and for the continuation of its current research activities. These negotiations seek some $12.5 million from both public and private sources. Commercial production is scheduled for early 1981.

The financing of HSA by the Ontario Government serves to emphasize the role Government can and should play in supporting the initial stages of R&D through a combination of fiscal incentives. The current round of financing reinforces this principle where part of the new funding will be public sourced and used for basic electrochemical research. The other portion of the current financing will be privately sourced and used for commercialization of its products. This emphasizes my belief that Government should avoid supporting the more mature stages of innovative development when market forces more properly should be the determining factor between corporate survival and growth or failure.

This returns me to the beginning of my talk and to the normally divergent market and societal perspectives of industry and Government. At least in HSA's instance common ground was found. There has been a coincidence of these goals and priorities which have facilitated a close interaction of HSA with both the Ontario Government and the EPA towards mutually understood and agreed to objectives.

Question (Chairman Roy N. Gamse): I would like to ask if any of the panelists would like to make any sort of brief comment on how the regulatory agencies can act in a way to encourage rather than discourage innovation.

We have heard from the speakers, several times, that the uncertainty as to what direction the regulations are going to take and that the constantly changing regulations can inhibit innovation; and also, in the case of metal-finishing where the existing program to develop regulations was an incentive for innovation. Have you any watchwords for the regulators as to how we can avoid obstructing and, in fact, spur on innovation?

Response (Tobias Anthony): It is very difficult for the regulators to employ flexibility. I think the way the Clean Air Act, in particular that of 1977, is written, the regulators must impose on the pollution sources the requirements of the Act as described in New Source Performance Standards.

As long as there is conflict over the imposition of these regulations, it is difficult for anyone close to commercialization or in the pilot stage on a development to proceed to commercialization until those conflicts are resolved and stay resolved for at least the pay-back period.

We are all faced with investment decisions that require a pay-back period. I can give you an example. We started working on the pulser under the old system about 12 years ago. And we did it on the basis of what we thought then, that particulate control would in fact get tighter. But when the next source performance standard came out and called for .03 pounds per million Btu, our work was justified; if they had called for one pound per million Btu, there wouldn't be any need for the pulser and that would have nullified some 12 years of development work.

In the existing law, there is not enough flexibility for EPA. But I do think that the aspect of emission offset and banking and trading of emissions is all begging the issue. I don't see that those policies are going to have much impact on resolving just when companies are going to buy pollution control equipment and when we are going to site plants and install pollution control equipment. I just don't think there is much you can do to stimulate us in industry.

FEASIBILITY OF A FEDERALLY FUNDED SMALL BUSINESS INVESTMENT COMPANY FOR FINANCING ENVIRONMENTAL VENTURES (1)

Leonard E. Smollen
Molly A. Levin
Venture Founders Corporation

INTRODUCTION

Research in the last few decades has led to a general recognition of the importance of small businesses to the vitality of innovation in the United States.

An early Government-sponsored study in 1967 found that two-thirds of major inventions in the decade after World War II, 1946-55, resulted from the work of independent inventors and small companies (2). These inventions included some of the things we take for granted now - Xerography, Polaroid cameras, insulin, and air conditioning among them.

A study of 310 major U.S. inventions of the next two decades, 1953-1973, confirmed the earlier findings, although the proportions were not quite so dramatic (3). This study showed the following relationship between innovations and the size of the originating business.

Table 1. Major U.S. innovations by size of originating firm.

Size of Firm	Percent of Innovations
Firms with less than 100 employees	24
Firms with 100 to 999 employees	24
Firms with over 1,000 employees	52

Not only do smaller firms produce a significant proportion of major innovations, but they apparently do so at lower cost and with greater efficiency than the larger firms. An estimation made by the National Science Board of the relative costs of innovations in firms of different size is shown in Table 2 (4).

Table 2. Estimated relative cost of major innovations by size of originating firm, 1953-1973.

Firm Employee Size	Relative Innovation Cost
1 - 1,000	4.2
1000 - 10,000	16
10,000 +	100

The table shows that for the 1953-1973 period, smaller firms produced innovations at about 1/25 the cost of the largest firms and 1/4 the cost of the middle-sized firms.

Another researcher compared firms with less than and more than 1,000 employees and concluded from empirical evidence that:

- The ratio of innovations to sales was about 1/3 greater in the smaller firms.
- The ratio of innovations to R&D employment was 4 times greater in the smaller firms.
- The cost to maintain an R&D scientist or engineer was 1/2 as much in the smaller firms (5).

On the basis of these and other studies, Government and industry researchers generally agree that whatever the exact percentages may be, individuals and small businesses are substantial sources of technological innovation, and they make their contribution more efficiently than larger businesses.

This background suggests that one highly promising way to increase the rate at which new products are developed and marketed in the environmental field is through the encouragement and nurturing of small environmental technology businesses created for that purpose.

PROFESSIONAL VENTURE CAPITAL AND ENVIRONMENTAL VENTURES

Generally, marketplace economics serves well to encourage capital flow to ventures that have acceptable financial risk/reward ratios, and business development is shaped accordingly.

Periodic shortages in investment capital, such as was evident in the early to mid-1970's, have a substantial deterrent effect on the formation of new businesses and the expansion of existing businesses. Shortages in capital supply affect the founding and development of businesses in all fields, however, without marked preference.

Today, more venture capital is available in the U.S. than has been the case since the late 1960's. Unfortunately, surveys made by the authors in carrying out a study for the EPA suggest that it will not flow in any considerable quantities to new or young environmental technology ventures primarily for two reasons: (a) Environmentally-related ventures are regarded by many venture capitalists as unacceptable investments because of their dependence on Government regulations that can "make or break them," and (b) Many venture capitalists prefer to invest in companies with a proven track record and to avoid the higher risks they suppose to be associated with investing in start-ups or very young and small ventures (6). That these do not always involve higher risks was shown in a 1971 study by Faucett (7).

Nonetheless, this means that the very type of businesses that might make innovative contributions in the environmental field are likely to have great difficulty in obtaining any of the venture capital so evident today.

An examination by the authors of reported financings by the 80 to 100 venture capital groups most active in early stage financings revealed that during the period 1977 to 1979 only 20 environmental companies were financed among 625 companies receiving venture capital, an approximate average of 7 per year. Among the 20 that were financed, only 5 were clearly start-up or first-stage ventures, the others being mostly in third-stage development.

A follow-up survey by telephone of some of the leading venture capital organizations revealed in some detail the reasons for the general disenchantment with environmental businesses in the venture capital industry. Exhibit 1 summarizes the comments of the investors who were contacted.

Exhibit 1. Venture capitalists' outlook on environment-related businesses.

- Venture capitalists surveyed were generally hesitant or negative about investing in pollution control companies because:

  "The market is somewhat determined by Government fiat."

  "It's hard to determine the extent of enforcement - you think the market is one thing but because of low enforcement levels, it can turn out to be another thing altogether."

  "Pollution control companies are dependent on Government money for municipal projects, etc., but the big dollars are in big process companies (paper mills, textiles, chemicals) that want established suppliers with reputations already earned."

  "Government regulations can make or break a company."

  "Most of what's being done is not new, not commercially exciting - no unique products with good prospects."

  "Invested in one company making water pollution control equipment. It took 6 years from financing until bankruptcy. There were no profits in the business. Will never touch the field again - anytime you get into a field that's regulated, you're asking for trouble."

  "With regulated industries, you have very little margin in which to operate."

  "A lot of deals we saw required a high capital expenditure - pilot plants, etc. - too high a risk."

  "Basically pollution control companies aren't making money. If the biggies can't make money, how are the small ones going to make any?"

"The Government created the industry and now is backing off on standards and letting the industry come down around their ears."

"Municipal market for water pollution control has fallen apart altogether as Government is not releasing funds; industrial water pollution control lacks market because most are in compliance; air pollution part of the industry is waiting for new standards; big companies have most of the market; and there's nothing new in technology, therefore no incentive for small new companies."

- Some venture capitalists were not deterred by industry characteristics:

"There are innovative techniques waiting to be applied to energy, resource recovery and radiation monitoring areas."

"The industry's regulation has little to do with it - telephone industry is regulated too, and there is investment and innovation there."

"Although EPA regulation takes an element of control out of the hands of management and adds to their problems, still, if they have something to offer, it would not hinder investment. What they offer should produce economic benefits, not just social benefits."

Clearly, several attitudes prevail: There is a great deal of reluctance about investing in an industry whose health and growth are largely functions of Government decree and enforcement. Some venture capitalists fail to be attracted by the products and processes offered. Other businesses in the environmental industry appear to have lost some of their pollution-control markets either because Government funds for purchases have been curtailed or because standards have already been met.

While venture capital apparently avoids unproven environmental businesses and fails to see much new in their product offerings, there are at the same time indications that research and development activities are ongoing in the environmental field, and their potential for innovation and commercialization needs to be assessed. Some of these could be candidates for venture capital investment.

Preliminary questioning of personnel in only a few EPA laboratories and other Federal agencies revealed that there are at least several hundred annual requests from large and small firms and individuals for funding of research and development. The National Science Foundation and the Department of Interior found no dearth of applicants for their limited funds to develop environmentally-related ideas. In the last year, funds available for early-stage development of potential environmental products have become even more scarce as some Government agencies have withdrawn R&D support in this field in favor of EPA stewardship of such activities. To date, EPA support of R&D has apparently emphasized basic research more than R&D directed at commercializing innovations.

The current Government practices, together with the aversion of many private venture capitalists toward the field can create a real capital shortage for innovative environmental technology ventures, while at the same time there is a great deal of venture capital available to many other technological enterprises.

Under the circumstances, it is reasonable to conclude that an increased availability of venture capital to qualified and selected entrepreneurs and ventures involved with environmental technologies and products could contribute to an accelerated rate of innovation in the field.

We propose that such capital be provided by a Small Business Investment Company (SBIC) dedicated to financing environmentally-related ventures. The proposed SBIC would be capitalized equally by private investors and by the EPA and would seek leverage of its equity through loans from the SBA.

Through its participation in an SBIC, the EPA could:

- Accelerate the commercialization of new and improved environmentally-related products.
- Provide seed capital to qualified businesses rejected in the usual capital markets.
- Increase the transfer of technology from laboratories to the marketplace.

A DEDICATED SBIC FOR FINANCING ENVIRONMENTALLY-RELATED VENTURES

SBICs are privately operated small business investment companies licensed and regulated under the Small Business Investment Act of 1958. To receive a license, an SBIC must have a minimum of $500,000 of private capital, and may be required, in some areas of abundant capital supply, to have a minimum of $1,000,000 of equity.

Leverage of private investors' capital contributions can be obtained through low-interest loans from the Small Business Administration (SBA), in amounts up to $3 for every $1 of private capital, or $4 for every $1 of private capital if the SBIC has already invested 65% of its equity in ventures.

Federal or State agencies may contribute capital to the SBIC's equity, and until a few weeks ago, these agency funds could be leveraged in accordance with a formula set forth by the SBA. However, in response to a Comptroller General's recent decision in one such case (see Appendix B), the SBA has now stopped its leverage of agency contributions. The decision does not affect SBA leverage of equity contributions from private investors.

An SBIC is limited to investments in SBA-defined small businesses. The current SBA definition of a small business is one that has a net worth less than $6 million and has an average after-tax income for the preceding two years of less than $2 million. There are also annual sales and employment standards that may define a small business and these vary from industry to industry.

SBA regulations provide that the SBIC cannot own more than 50% of any venture, and cannot invest more than 20% of its equity in any single venture.

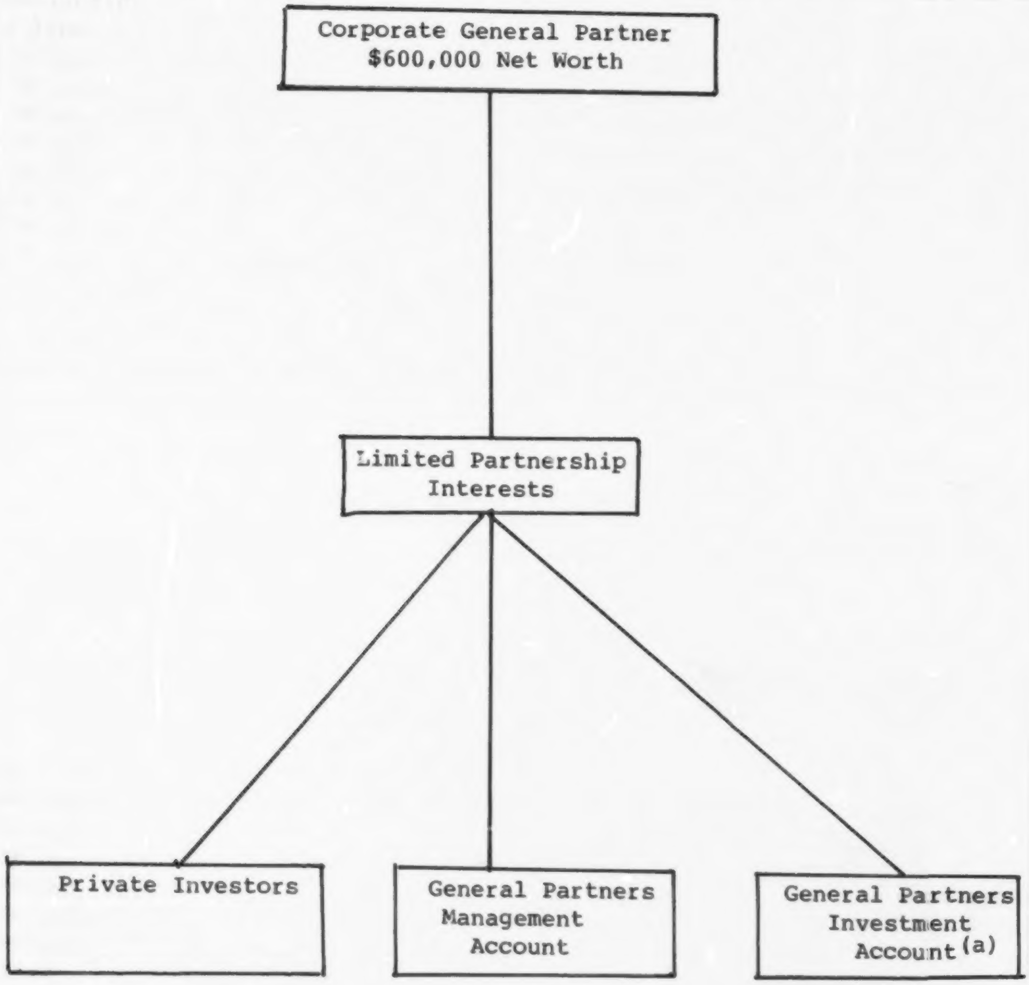
Although diversified investments are the rule, SBICs can be established, with SBA approval, to deal with a single industry; and there are, among some 300 existing SBICs, a number dedicated to single industries (8).

The dedicated SBIC we propose would be organized as a limited partnership for tax efficiency, and with a capitalization of $6,000,000, half secured from private investors and half from the EPA. This capitalization is large enough to permit the SBIC to continue financing ventures for a number of years. (In a limited partnership, taxable income and tax-deductible losses pass to the limited partners without any tax at the partnership level. The liability of the limited partners cannot exceed their investment in the partnership, and they must play no part in the management of the partnership.)

SBA currently requires that a limited partnership SBIC have a sole corporate general partner and that the limited partnership SBIC receive a ruling from the Internal Revenue Service (IRS) that it qualifies as a partnership for tax purposes. Because of IRS requirements imposed on corporate general partners, most non-SBIC venture capital partnerships are organized with individuals as general partners. SBA has recently published for comment a proposed rule that would allow individuals to serve as general partners in a limited partnership SBIC. If this rule is adopted, serious consideration should be given to the use of individual general partners for the SBIC. We should note that the individual general partners assume unlimited liability for the partnership.

The organization and capitalization that is proposed for the SBIC is shown in Figure 1 and Table 3. This form of organization and capitalization is similar to one used by an existing SBIC and has been designed to satisfy a series of rules and regulations of the IRS (Appendix A) and the SBA (Appendix B) concerning the organization of the SBIC, its management, net worth requirements for its sole corporate general partner, and restrictions on limited partner interest in the general partner.

Figure 1 and Table 3A show the organization and limited partnership interests of the proposed SBIC. For tax reasons noted below, EPA participates in capital gains and losses through a "General Partners Investment Account" and not directly as a limited-partner investor.


Corporate General Partner
$600,000 Net Worth
Limited Partnership Interests
Private Investors
General Partners Management Account
General Partners Investment Account (a)

(a) EPA participates in capital gains and losses via this account.

Figure 1. Proposed organization and capitalization of $6 million SBIC.

Table 3A. Proposed organization and capitalization of an SBIC dedicated to financing environmental ventures.

Limited partnership interests.

Limited Partnership Interest	Capital Investment	% of Gains or Losses
Private Investors	$3,000,000	55%
General Partner's Investment Account (EPA's participation in gains and losses)	$3,000,000	25%
General Partner's Management Account	-------------	20%
	$6,000,000	100%

In order to provide an incentive to private investors to invest in the SBIC, it is proposed to give them a higher percentage of gains than their invested capital would normally purchase: i.e., a 55% interest vs. the 40% share they would normally receive for their capital contribution. We believe that private investors will want a higher-than-average proportion of the returns because they are uneasy about the narrow focus of the SBIC and investments in businesses whose future growth is dependent on Government regulation, and also because higher-than-average management costs will be involved in finding good "environmental deals" for investment.

Until all the capital investments have been recovered, all net operating income and losses and all realized capital gains and losses would be allocated to the private investors and the "General Partners Investment Account" in the proportions shown in Table 3A (i.e., 55/80 to the private investors and 25/80 to the Investment Account). Thereafter, 80% of income, gain and loss would be allocated to the "General Partners Investment Account" and the private investors and 20% would be allocated to the "General Partners Management Account."

If desirable, a limited partnership structure allows an allocation of losses to private investors to be different from their allocation of gains. In any case, any capital losses associated with a private investor's SBIC stock is deductible in full from ordinary income.

The "Management Account" of the limited partnership interests provides a way for the managers of the general partner to receive a 20% interest in the realized capital gains. This is the typical "incentive" percentage received by management to attract the highly skilled people who can invest venture capital successfully.

Table 3B. Proposed organization and capitalization of an SBIC dedicated to financing environmental ventures.

Corporate general partner shareholdings.

General Partner Shareholders	Participating Preference Stock		6% Cumulative Preferred Stock		Common Voting Stock	
	$	%	$	%	$	%
EPA	$3,000,000	100	$580,000	100	---	---
Management of General Partner	----------	----	----------	----	20,000	100
	$3,000,000		$580,000		$20,000	

Table 3B details the ownership of the corporate general partner. As shown in the table, shareholders in the corporate general partner are EPA and the managers of the fund. The somewhat unusual structure in which EPA holds two classes of preferred stock is established in response to two separate IRS requirements to obtain tax treatment as a partnership.

- The general partner must maintain a net worth equal to 10% of capital contributions when these contributions exceed $2.5 million (the percentage rises for smaller amounts of capital) and this net worth must not include any interest the general partner has in the partnership.

- The limited partners cannot own more than 20% (computed in number of shares or dollar value) of the stock of the corporate general partner. The proceeds from the $3 million of participating preference stock will be invested in the partnership as the "General Partner's Investment Account." As the owner of this stock, EPA will be entitled to any gains or losses (less corporate tax) received by this account. The participating preferred stock serves to provide EPA with an interest in the partnership without jeopardizing the tax status of the partnership. If EPA invested this money directly as a limited partner, it would violate the IRS condition that no limited partner can own more than 20% of the stock of the general partner.

The organization and capital structure of the SBIC that has been described allows $3 million of EPA's capital contribution to be used for investment purposes and requires the additional $580,000 of EPA funds to be invested in the corporate general partner together with a $20,000 investment by the managers to meet the net worth requirement. If SBA decides to allow individuals to serve as general partners, the $580,000 of EPA funds would not be needed.

Notwithstanding all the uncertainties associated with such forecasts, projections were made of the proposed SBIC's investment pattern, revenues and expenses to obtain a sense of how much the proposed SBIC might invest and how much SBA money it might reasonably borrow and use in its initial seven years of operation. The results are shown in Table 4.

Table 4. Capital employed and leverage on EPA funds ($3,580,000) with projected investments in 7 years of $11,400,000 in 15 to 20 businesses.

	7-Year Projection	Maximum
Private Investors	$ 3,000,000	$ 3,000,000
SBA	$ 7,200,000	$12,000,000(a)
Total Non-EPA Funds	$10,200,000	$15,000,000
Leverage on EPA Capital	2.8	4.2
Potential Additional Unsubordinated Borrowing By Ventures	$ 9,000,000	$12,000,000
Leverage on EPA Capital with Unsubordinated Borrowing	>5	>7

(a) Maximum SBA funds do not include any SBA leverage of EPA's equity contribution, in accordance with SBA's recently changed policy (see Appendix B).

Our projections indicate that within the first seven years, funds anticipated from SBA together with the capital contributed by private investors would amount to 2.8 times the EPA contribution, with an eventual maximum potential of 4.2 times the EPA investment. If we add to SBA and private capital an estimate of the additional unsubordinated borrowing available to ventures, then the leverage increases to more than 5 times the EPA contribution within 7 years, and potentially to a maximum of more than 7 times the EPA contribution.

INVESTMENT CRITERIA

Possible Criteria for Venture Investment

A tentative set of criteria for environmental ventures to be financed by the proposed SBIC was drawn up as a result of preliminary discussions with EPA. Criteria considered to be appropriate to identify ventures for evaluation and potential investment are:

- Emphasis on new and young ventures seeking to market new products, processes, or services;
- Product, processes and/or services of ventures to involve one or more of the following activities: air, water or radiation pollution control equipment, pollution control instrumentation, disposal of waste and toxic or hazardous materials, resource recovery, process changes to reduce pollution;
- Pure construction activities and consulting services to be excluded;
- Focus on ventures with products, processes or services that are ready or nearly ready for commercialization;
- Potential for profitable sales of $2-4 million in 3-5 years and more than $10 million in 10 years;
- Potential for a compounded annual return on investment (ROI) of at least 30%;
- Initial investments in ventures to be less than $500,000.

The above criteria represent current thinking and could be supplemented or revised as warranted by the needs and trends in environmental technology.

OPERATING PRACTICES

The SBIC's objective will be to make 2 to 4 investments per year. Where necessary and warranted, investment syndication with other venture capital firms will be sought.

The financing of environmentally related ventures by a dedicated SBIC will entail greater search, venture development, and evaluation costs than are usually incurred by a venture capital organization investing a comparable amount of money. There are two reasons for this. First, the dedicated SBIC has a much smaller universe of opportunities from which to select an investment than a venture capital firm free to select an investment in any technology or industry. The inevitable result is the expenditure of more time and money to find good "environmental deals." Second, to foster the commercialization of environmental technologies, the dedicated SBIC will play a more active role in seeking out and helping to develop environmentally-related ventures than is taken by many venture capitalists.

The annual management expenses of the proposed SBIC are estimated to be about 6-7% of its equity capital in its first 3 or 4 years vs. 3-5% for a typical venture capital firm with comparable investment capital. The private investors' larger-than-normal proportion of capital gains is intended to compensate for a reduced investment return caused by these larger operating costs together with the lack of industry diversification resulting from the environmental focus of the SBIC.

A thorny problem, for which no consummate solution is easily available, concerns the vulnerability of a Government agency such as the EPA to potential questions of conflict of interest. The potential conflict arises when EPA seeks to advance its authorized mission by both investing in environmental businesses and at the same time setting and enforcing standards that determine the markets for the products of those businesses. One preventive measure is for the managers of the proposed SBIC to make investment decisions in which EPA and its personnel play no part, but which are guided by criteria jointly established at the outset.

PRECEDENTS FOR EPA PARTICIPATION IN AN SBIC

While the concept of Federal agency participation in equity funding of private enterprise may appear to be novel, several Federal agencies have provided equity funds to privately operated Small Business Investment Companies (SBICs) or minority enterprise Small Business Investment Companies (formerly called MESBICs, now 301(d) SBICs). In two examples, the Federal agency directly purchased stock in the SBICs. In the other examples, the Federal agency participated by granting moneys to an intermediary public purpose organization, which then used the money to purchase ownership in an SBIC or MESBIC. In turn, the privately operated SBIC or MESBIC provided equity, loan, or both types of financing to small businesses.

In one prominent and recent case, a Federal agency, the Department of Transportation, made direct investments totalling $9.6 million in seven existing, privately managed MESBICs with direct ownership of the stock by the U.S. Treasury, and physical stewardship of the stock within the Department's Minority Resource Center. In this case, the Agency, nominally through the Minority Resource Center of the Federal Railroad Administration, purchased nonparticipating 3% cumulative preferred shares in seven different MESBICs. These shares are subordinate to preferred shares held by SBA in these companies. (Under the SBIC regulations, SBA may purchase preferred stock in MESBICs, but can only purchase or guarantee subordinated debentures of regular SBICs).

Department of Transportation spokesmen have expressed the Agency's interest as that of encouraging and providing capital for railroad-related minority businesses. The only financial return the Agency will seek is the 3% annual dividend and eventual return of the investment itself. We have already noted that DOT funds invested in these MESBICS will not be leveraged by the SBA.

Another example of direct agency purchase of stock of Small Business Investment Companies is the SBA itself. Under the Small Business Investment Act, Section 303 (C), the SBA is authorized to purchase preferred securities of SBICs established under Section 301 (d), authorizing licensing for SBICs established solely to provide venture capital to disadvantaged owners or businesses. During 1979, SBA purchased $15.4 million of preferred stock from such SBICs in 19 separate sales.

Examples of agency participation in the funding of SBICs and MESBICs through an intermediary organization are:

- U.S. Community Services Administration (CSA) - the CSA is authorized to provide financial and other assistance to community development corporations (CDCs), whether non-profit or for profit, including equity capital for purposes of starting, expanding, or locating businesses in or near the area they serve. CSA has made grants to a number of CDCs, which used the money to fund or establish SBICs or MESBICs. The SBIC's or MESBIC's shares are owned by the CDC. For example, Siete del Norte, a Santa Fe CDC funded by CSA, used its funds in turn to purchase ownership in Associated Southwest Investors, a MESBIC. Similarly Telecu Investment Co., a MESBIC, received its funding from Telacu CDC in East Los Angeles, California.

- HUD - In the Model Cities Program, HUD funds were provided to local economic development corporations which used the money to buy shares in SBICs and MESBICs whose purpose was to invest in small businesses in the areas HUD was attempting to impact. This equity funding was supplied by HUD under its general grant-making authority to implement the Demonstration Cities Act.

- City of Los Angeles - In 1975, the City of Los Angeles made available a $1 million grant to the Los Angeles Economic Development Corporation to augment the capital of its wholly owned, for-profit MESBIC--Business Equity and Development Corporation. Under the provision of the grant agreement, so long as the corporation is not dissolved and/or changes its nature, the City has placed no restrictions on, nor does it have any recourse to the funds. The Corporation can use the funds in any manner consistent with all the incidents of ownership over the funds.

Clearly, these examples provide precedents for EPA to purchase an equity in an SBIC.

ASSESSMENT OF FEASIBILITY AND PROBLEMS

There are three main questions involved in the feasibility of the proposed SBIC:

1) Can the proposed SBIC attract private investors?

2) Does the EPA charter permit it to invest in an SBIC dedicated to financing environmental ventures?

3) Will there be enough good candidates for investment?

With respect to the first question, our investigation of private investor interest is not yet completed. We intend to interview a sample of investors to find out their attitudes toward such an SBIC investment. Our experience indicates that their return on investment in the proposed SBIC would have to equal or exceed other venture capital opportunities if the SBIC is to attract them. The proposed structure, in which the private investors are allocated a share of the gains larger than warranted by their capital contribution, should help to attract private investors.

The second question, regarding EPA's authority to invest in an SBIC, is currently under study by EPA counsel. As we have shown, there are precedents both for Federal agency direct purchase of stock in SBICs and for indirect contributions of capital through intermediary public purpose organizations.

Authority for agency participation stems in some examples from an explicit mandate in the agency's enabling legislation and in other cases, from interpretations of the general language in the legislation establishing the agency and setting forth its mission.

The third question - whether or not there will be enough good candidates for investment - merits a more detailed and somewhat qualified answer. Data obtained in our limited search and survey of venture capital transactions in the environmental field led us to conclude conservatively that some 250 to 350 environmental ventures probably seek financing from the venture capital community during a year. Our telephone interviews with only a few Government laboratories revealed also that many requests are made for funding of environmental R&D, some of which may have commercial potential and could be candidates for venture capital investment.

The objectives of the proposed SBIC would be to make 2 to 4 investments per year. Venture capital experience is that, at most, 2% to 3% of "deals" seen are worth financing. The proposed SBIC would want/need to review, therefore, approximately 100 to 160 opportunities per year from which to select its investments. We think such a "deal flow" is realizable without diverting many deals away from existing venture capital firms. The reasons for this are as follows:

- Investable, early-stage environmental technology deals are being bypassed by the venture capital community because of biases against environmental investments and/or startup situations. This deal flow will be available to and should provide investment opportunities for the proposed SBIC.

- The very existence of a dedicated financing source can be expected to induce entrepreneurs (who might otherwise not do so) to start or expand environmental technology ventures and seek venture capital.

- EPA and other Government agencies can refer entrepreneurs and young ventures involved in government-funded R&D to the SBIC for financing consideration. It is possible that EPA may want to establish an innovation incentive program similar to that of the National Science Foundation, in which R&D funds are granted in steps: first, a modest amount sufficient to determine the feasibility of undertaking a research project; and second, the funding for the actual research and/or development, granted only on the condition that the applicant has secured a venture capital commitment for the commercialization stage to follow if the R&D is successful. Examples of products/processes developed under EPA contracts that may be candidates for future commercialization are:

  - Emergency collection system for spilled hazardous materials
  - Ocean systems barrier
  - Multipurpose gelling agent
  - Spill alarm system
  - Carbon reactivator (mobile)
  - Specialized ultimate disposal processes
  - Fail-safe transfer line
  - Hazardous materials identification kit

- A methodical and active search for entrepreneurs and ventures involved with environmental technologies can be undertaken and can be expected to provide a larger number of investment opportunities than would otherwise be available to the SBIC for review. Such a search can employ public relations techniques, mailings, and referrals from people whose work brings them in contact with entrepreneurs and new ventures. This approach to stimulating "deal flow" has been successfully used by our firm, Venture Founders Corporation, in many places in the United States, Canada, and Great Britain.

CONCLUSIONS

The conclusions we have drawn as to the feasibility of the proposed SBIC can be summarized as follows:

- Can the proposed SBIC attract private investors? Our investigation is not yet completed, but we are optimistic that the prospect of a return somewhat greater than warranted by the private investors' capital contributions will help to attract them.

- Does the EPA charter permit its participation? While this is still under study by EPA counsel, there are a number of precedents that would suggest an affirmative answer.

- Will there be enough good candidates for investment? We believe that there can be because of the declining interest of venture capitalists in environmental technology ventures and if all the methods we have described are used to generate a flow of investment candidates. However, a conclusive response to this question can be made only as a result of an actual trial.

Our study thus far has caused us to be optimistic, therefore, that the establishment and operation of a dedicated SBIC could indeed contribute to the acceleration of innovation in the environmental technology field.

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Appendix A. IRS Conditions for Partnership Tax Treatment of Limited Partnerships with Sole Corporate General Partner.

For a limited partnership SBIC with a sole corporate general partner to receive Federal tax treatment as a partnership, the following conditions must be met:

1. The limited partners cannot own, directly or indirectly, more than 20% of the outstanding stock of the corporate general partner (or any other member of an affiliated group of which the corporate general partner is a member). It is unclear as to whether this condition applies to the number of shares of all classes of stock or of voting stock or to the equity capital of the general partner. VF's tax advice is that it should be satisfied on the basis of the number of common and preferred shares as well as the dollar value.

2. If the total capital contributions to the partnership are less than $2.5 million, the corporate general partner must have a net worth of at least $250,000 or 15% of the capital contributions, whichever is the lesser. If the capital contributions exceed $2.5 million, the net worth of the corporate general partner must be at least 10% of such contributions. For this test, net worth excludes any interest the general partner may have in the partnership.

3. The purchase of a partnership interest by a limited partner may not entail either a mandatory or discretionary purchase or option to purchase any type of security of the general partner or its affiliates.

4. The organization and operation of the partnership must be in accordance with the relevant state law.

5. The interest of the general partner in each material item of partnership income, gain, loss, deduction or credit must equal at least one percent of each such item at all times during the existence of the partnership.

6. The aggregate deductions to be claimed by the partners as their distributive shares of partnership losses for the first two years of operation of the partnership must not exceed the amount of equity capital invested in the partnership.

7. A creditor making a nonrecourse loan to the partnership must not have or acquire at any time, as a result of making the loan, any direct or indirect interest in the profits, capital, or property of the partnership other than as a secured creditor.

It is important for the SBIC to meet these conditions. If they are not met and the SBIC is classified as an association taxable as a corporation, any capital gains generated would be taxable directly to the association at corporate rates. Distributions of such proceeds to individual partners could again be subject to tax - in the worst case, as dividends.

Appendix B. Some Important SBA Regulations and Policies Regarding Limited Partnership SBICs.

A limited partnership SBIC must have a sole corporate general partner organized solely for service as such. Before extending any loans to a partnership SBIC, the SBA requires that the SBIC furnish it with an IRS ruling that it qualifies for tax treatment as a partnership.

An SBIC must have at least $500,000 of private capital and if located in metropolitan areas with heavy concentrations of capital, private capital of $1 million can be required. An SBIC's capitalization can include nonprivate (e.g., EPA) funds.

According to statute and regulations, an SBIC may be eligible to borrow from SBA up to three times its private equity capital. If and when it has more than 65% of its available funds invested in venture capital situations, an SBIC may be eligible to borrow from SBA up to four times its private equity capital. An SBIC cannot commit more than 20% of its equity capital to any one venture nor can it own more than 50% of a business it finances. Until a few weeks ago, Government agency contributions to the equity capital of an SBIC were included for purposes of SBA leverage, under an SBA formula that allowed $10 of agency funds to be leveraged for every $1 of private investor capital above a minimum of $500,000. The contribution, a few months ago, of some $9 million of capital by the U.S. Department of Transportation (DOT) to 7 different SBICs, and their subsequent request for SBA leverage under then prevailing regulations caused the U.S. Comptroller General's office to issue a decision that disallowed any SBA leverage of DOT funds, apparently under the philosophy that one Government agency should not leverage the funds of another. Although the Comptroller General's decision applied only to the DOT case, the SBA has asked for a clarification that would extend the decision to all other Government agencies. The decision does not affect SBA leverage of equity contributions from private investors.

An SBIC is limited to investments in SBA-defined small businesses. The current SBA definition of a small business is one that is independently owned and operated, is not dominant in its industry, has a net worth less than $6 million and an average after-federal-tax income for the preceding two years of less than $2 million. In addition, a firm may qualify as small either under an employment standard or according to the amount of annual sales. Both of these standards vary from industry to industry and should be checked with the SBA in each case.

Generally, an SBIC must have from 60% to 70% of its equity capital committed to ventures before SBA will provide any debt. This practice is intended to insure that an SBIC invests its private dollars first and that SBA funds are not left idle. (Because it takes time to invest funds wisely, this policy can mean that an SBIC may not obtain much SBA debt in its first few years of operation.)

SBA loans can be obtained in advance of venture investments on the basis of a plan that details how the SBA debt will be used. Alternatively, SBA can provide loans to an SBIC for funding specific ventures on an as-needed basis. Such loans are made to SBICs each month and involve a 30-day turnaround.

Once an SBIC's initial net worth is reduced 25% by operating losses and/or realized or unrealized losses on investments, SBA will not provide any debt to that SBIC. A 50% decrease in its initial net worth causes an SBIC's capital to be impaired and, in this condition, an SBIC is in default on its SBA debentures. Capital or operating losses can be made up by realized or unrealized capital gains. (Realized capital gains are very unlikely in the early years of an SBIC making early-stage venture investments.)

To qualify for maximum (4 times) SBA debt leverage, there can be no amortization of an SBIC loan to a venture for at least three years. Funds of an SBIC that are not invested in ventures must be deposited in a bank insured by the Federal Deposit Insurance Corporation (FIDC) or may be invested in direct or guaranteed obligations of the United States, in a savings account insured by the FDIC or in Certificates of Deposit maturing in a year or less and issued by a bank insured by the FDIC.

The SBA requires that an SBIC have no ties or restrictions on the investments it makes with its capital. An SBIC dedicated to financing environmentally related businesses will require a "special exemption" from SBA on this condition. Currently, the only areas where SBA will not grant a special exemption are for SBICs that want to restrict their investments to real estate or construction ventures. The pollution-control area is sufficiently broad and varied that obtaining a special exemption should present no problem.

Question (Unidentified Speaker): What is the incentive to do a proper indepth analysis of the technology around which you want to create a venture, when the risk appears to be primarily to Government funds?

Response (Leonard E. Smollen): That's not quite true. As a matter of fact, probably the greatest incentive to do that analysis is the 20 percent by which the management can reduce its capital gains. To the extent that the analysis is not done and that venture fails, the managers don't get their reward.

I would also note that probably a primary factor in a decision to invest in a venture concerned with environmental technology or anything else, is the quality of the management. That can be a factor that takes on even more importance than the technology itself.

If good management isn't there, the investment won't be made.

Question (Unidentified Speaker): We heard from Mr. Anthony earlier that over the next 10 to 20 years we might in fact consume the entire gross national product in pollution control, if we really solved the problem as defined by the EPA and certain elements in Congress. To what extent will one aspect, however well leveraged, solve that kind of problem?

Response (Leonard E. Smollen): Let me say a couple of things. I would make three comments on that. Everyone seems to focus on the leverage here. That is not the crucial item. You will notice that over the seven-year period, the debt equity ratio to put in the ventures is about 1 to 1. You really don't want to overleverage the ventures. That is the first point.

The second point is that if this concept works I would see more than one such Small Business Investment Company (SBIC). The third comment is that Digital Equipment Corporation was started on $70,000 from American Research and Development. So it's hard to say exactly where that goes. It's also been the source of several spin-offs in the industry. One could almost argue that a whole sizable subset of the computer industry has been created, based on initial small investment.

FORM FOR EPA CONFERENCE MANUSCRIPTS

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TITLE (After first page, use this line for manuscript)

FINANCING THE NEW POLLUTION CONTROL TECHNOLOGY VENTURE

James H. McCall, Partner
McCall, Dendy & Vande Pol

Success in raising capital for commercial exploitation of new pollution control technology has three elements: planning, acuity, and luck. No matter how thorough the approach to raising capital, risk probabilities must be recognized and calculated for developmental and initial operating expenses and capitalization assumptions must provide for them.

The application of these elements are common to ventures which will provide services or products, whether through economies in operations or innovations in technology.

The new pollution control technology venture has two major financial considerations for its growth: capital for itself and financing for its customers.

Technological innovations are generally more visibly undertaken by small businesses than by large. This would indicate that in addition to the financial issues faced by the new environmental technology venture for its own purposes, it must have a knowledge and sophistication in how to fund its customers' needs as well as who in many cases will also be capital short.

Therefore, the business plan for the new venture should incorporate significant considerations of sales financing. Following are the key factors in this financing.

1. Knowledge of the Dynamics of Markets, e.g. Deadlines, Standards and Enforcement Activity.

The ability to profitably deliver services or products to satisfy customer demands is the key driving force for a new venture. There must be evidence of an adequate amount of research of the volumes, scope and triggering mechanisms for demands among potential customers for the product or service. In addition to the compliance requirements and enforcement pressures, today's markets are also very sensitive to the cost savings features of new technologies, particularly how they can be employed in reducing labor and other variable production expenses. The pricing mechanism and development for the product or service must be researched and demonstrated and an ability to deliver an adequate volume of products or services timed to the needs of customers must also be demonstrated.

Ten years of experience in pollution control financing have demonstrated that the marketing of technology services and financing are driven principally by deadline requirements of the United States Environmental Protection Agency and of local standards that are often tougher. There is much less of the classical demand typical for other marketing strategies.

The predictability of marketing success is governed by sensitivity to regulations and enforcement activity, consistency of sales efforts and credibility among clients. Without these features, the markets for innovative technology lose much of their vitality and predictability.

For example, marketing to the metal finishing industry has required patience as its main feature. Standards for this industry have been the source of almost continuous litigation between the EPA and the national trade associations for over five years. Each round of litigation pushes back the certainty of standards by several months, which means that there will be a significant crunch on companies if required to comply within the next two years. To ask that 5,000 firms undertake this investment indicates that there will be substantial capital requirements in an already uncertain market era. The ability to finance these projects will dictate many purchase decisions, as investment in compliance facilities is very often greater than the owners' original investment.

2. Control of Manufacturing and Assembly Functions and Adaptability to Changes in Market Dynamics.

This is the quality control element for the new venture. It is viewed as a measure of the reliability of the venture to supply services or products that the market research shows as having a chance of success. Many ideas are aborted because of the inability to assure viability and reliability. Up to two years should be allowed to develop the assurances of these elements, and in many cases the markets will change for a variety of reasons. Therefore, adaptability and flexibility are critical to assure the introduction of the new product or service on a timely basis.

3. Sensitivity to Customers' Needs and Abilities to Finance Pollution Control Technology.

The investment in pollution control facilities is often one of the largest, if not the largest, single investment that many small and medium-sized businesses will make. Its magnitude is reflected in major industries by the fact that pollution controls can represent between 20 and 40 percent of new project costs. The marketing of the new product or service should include an ability to gauge the financial capabilities of the potential purchaser to acquire those facilities. An important part of this is the ability to "fit" the technology when retrofitting facilities and whether it is the keystone in a new project. The new venture manager should be able to provide forecasts of the technology's results and impacts on the business operations of the potential customer. There should be an ongoing sensitivity to the various sources of project financing that can enhance the financial capacity of the customer.

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4. Management and Financial Controls as Reflected in Budgets, Objectives and Performance Measurement Techniques in Regular Financial Reports and Forecasts.

The chronologies of likely milestones and events of the venture's development should be played out by management. These planning techniques can be patterned after a number of published success stories in various venture capital references. This area requires the greatest acuity with a demonstration of ability to incorporate administrative and operating controls on the venture. These controls can be in the form of sequential and regular, sensitive indicators alert to variations from the planned development. Most valuable of all these components is probably the cash flow projections, organization and full understanding of the responsibilities and job elements of each of the principals in the venture. These elements and factors will form the core of business and financing plans. The plans can be as formal and as detailed as external financing sources require. This may range from a highly detailed and well-documented plan prepared for institutional types of venture capital investors, through summary plans that can be used with banks and commercial finance companies, to very general types of plans that can be used in dealing with investors or backers who are known personally to the venture founders. It must be emphasized, however, that this is only the final product of this planning, and that the planning process must include all of these factors to provide the maximum assurance of success.

These plans also would be used as a basis for a prospectus for potential financing sources, including both short and long-term debt and equity investments.

In the particular area of pollution control technology, customers of the venture may have a need for financing assistance, such as SBA's pollution control financing guarantees. The venture should have available expertise to help expedite sales financing and assure reliable funding of orders. A sale is impossible to close unless the customer is assured that the capital is available from either his internal sources or external ones. This is particularly true in marketing of pretreatment facilities to such industries as metal finishers and platers, and coal conversion projects for utilities.

Contingency planning must be extremely apparent in the first factor, as market dynamics are very likely to change as a result of litigation, legislation, or competition and changes among the customer targets. As mentioned, a two-year horizon is reasonable to expect in the planning process, and experience has demonstrated that major changes can occur in that period. Financing requirements for the venture will shift based on these dynamics as the planning, manufacturing, assembly functions change. There also may be changes along the customers' financing needs depending on the current status of this legislation.

With the recent elective changes in the Federal Government (November 1980), the market research should be extremely sensitive to reports of attitudes towards the Clean Water and Clean Air Acts, and managers of new technology ventures should be keeping in touch with trade associations and other contacts that can provide current apprisal of the whole spectrum of rumors and developments that may affect these markets. There must always be an awareness of what the perception of potential customers are about the impact of these changes, and how this will affect decisionmaking among them.

This discussion is aimed at both the independent entrepreneur or corporate new venture manager. In either case, these same elements apply whether the funding will come from internal or external sources. The venture in both cases should have the characteristics of an organized entity, i.e., partnership or corporation. In having the objective of the commercialization of the new technology, it should have the physical attributes of an operating business and have outside confirmation of the needs for its products or services.

As a new or independent venture, the most likely sources of financing, aside from the founders, will include banks, U.S. Small Business Administration, commercial financing companies, and venture capital firms including investment bankers. The last-mentioned can play an important role in advising the company and matching it with investors that are willing to take the type of risks that a new venture offers. In recent months many partnership forms of venture capital enterprises have been formed because of changes in the tax laws which have encouraged investment tax credit for these types of investments. No matter what the financing source, each will depend on articulate business plans and information on a consistent and periodic basis. The general environment for new pollution control technology venture is good particularly for those which emphasize that environmental improvement is a byproduct of improved productivity and efficiencies, better quality control, or energy conservation.

Question (Chris Pederson): How many startup ventures in the environmental field has your company funded?

Response (James H. McCall): Over the years I have been involved in about six to eight of them, and four of them have failed. For startups that is a good average.

Comment (Unidentified Speaker): Just one brief comment further. It has been very refreshing for me, as an entrepreneur, having started up a company in this field, to see at least in this last afternoon some amount of attention addressed to smaller industry requirements, something below investment requirements of $80 million.

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MARKETING NEW ENVIRONMENTAL TECHNOLOGY

Terry W. Rothermel, Senior Staff Consultant
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I want to believe that the reason why my address on marketing has been scheduled at the end of the conference is to remind us that no innovation will sell itself in this marketplace. Studies of successes and failures in new product innovation--particularly in Great Britain and the United States--have consistently demonstrated that the greater barriers to commercial success are ones of marketing and not technology. By analogy, successful participation in this conference will therefore be limited to those of you who have persevered through this marketing discussion.

Legislated Demand

The legislated nature of environmental markets has held very special problems for the sales forces of the pollution control industry. The difference between legislative potential and real opportunity has been in hindsight simple: enforcement. This industry has been notably dependent upon the efforts of regulatory agencies. This is one reason that pollution control businesses are now viewed as more unpredictable (i.e., less under the control of the corporation's own efforts) than other businesses in corporate portfolios.

Marketing is usually focused on meeting customer needs for an improved means of producing their own products. In this case, the need is an enforced requirement and the customer is more reluctant (than interested) in making a purchase. The marketing task is analogous, but probably worse, than selling life insurance to a clientele which would just as soon not think about death.

Many Market Segments

While it is relatively easy to account for more than $10 billion of annual pollution control expenditures, it is not as easy to find the large separable markets which are necessary to attract the interest of large corporations. Excluding products and services provided on the local level, the pollution control industry participates in only $2 billion to $3 billion of that annual expenditure market.

Further, the business opportunities are typically divided into many market segments: between air, water, solid and hazardous waste problems; between municipal, industrial, and utility customers; between equipment, instrumentation, chemicals, and services; or between capital and operating expenditures. In short, an apparent opportunity of more than $10 billion a year consists mainly of $50 million to $100 million market segments.

Growth, But Not Profits

The glamour which was associated with the environmental business in the 1970's proved justified in terms of real growth but not in profitability. Pollution control businesses, for example, have been exceptions to the popular consulting rule that higher profitability follows on higher market shares. No one is writing exposes on how this industry has exploited social problems and reaped excess profits.

We do not believe that attractive growth for this industry is over. The analogy of Japan, which has spent proportionately more moneys on pollution control in response to a more immediate problem, is evidence of a still higher "steady state." The juxtaposition of continued growth in population and economic activity against a constant ecology is another reason to expect a need for increased controls (and expenditure levels) over time. The glamour era of the environmental industry may be at an end, but its growth is not.

Regulatory Pushes and Pulls

Enforcement is generally marketing's best friend in environmental businesses. As noted, enforcement is the difference between potential markets and real orders. It can make reluctant customers take action. Sometimes, however, regulation and enforcement can work against long-term marketing effectiveness.

Technology-forcing standards, for example, can push marketing promises beyond proven technological capabilities. One of the most disturbing concepts that we heard during the 1978 study was that particulate control technology was being created in the contract and not in the pilot plant. It is naive to reason that companies can simply withdraw from such competition. Statesmen don't get contracts, they simply retreat from the field. When such systems fail to live up to promises, this only reinforces the claims of reluctant customers that the prescribed controls were impractical to begin with.

Another occasional blind spot of environmental regulation, which works against new technological development and the marketing of new products, are standards that tightly legislate a market around one approach and kill the market for another. Sometimes this happens when the focus is upon the "best available technology" and its associated "best" performance. When we are talking about new technologies, we need to recall again the "learning curve" realities that I noted earlier this afternoon. As we move into "steady state" in environmental regulation, I would hope that "best available technology" might better accommodate a range of developing approaches. This will be even more important in situations involving process and energy technologies. I have already seen a focus upon the best control performance result in reducing the competition among technologies for the best energy efficiency. I am sympathetic with the tremendous tasks that face EPA, but I think there is need to more closely review how new regulations may work against both innovation and competition.

Continuing Marketing Realities

There are several realities of pollution control businesses which will continue to affect the development and marketing of future innovative approaches. They are not likely to go away.

The reluctant customer still lives. There is hope that pollution control customers will in the end act rationally--that is to say, after they have exhausted all other possibilities.

Pollution control will remain an enforcement market. That condition will improve as regulation deals more with new plants and less with retrofit situations. In new construction, regulatory authorities have the license to operate in their pocket. In addition, the corporate pride associated with a new facility is more likely to extend to the pollution abatement aspects of the project and, therefore, to include more advanced technologies.

Research and development in pollution control technologies will remain risky. While technological development times may continue to exceed the timing of regulatory implementation, there is a chance that more research and development projects will find waiting demand in a "steady state" marketplace.

The operation of pollution control facilities will continue to be inadequate to the task. Enforcement for achieving compliance is not yet matched by the enforcement for maintaining compliance. Industrial plants will continue to be more interested in production operations than in "nonproductive" control operations. Municipalities will continue to have problems in funding and staffing treatment plant operations.

Price will continue to have priority over performance in pollution control purchasing. This would not be true, of course, if price and performance were put in their proper and equal place, i.e., in the value equation of performance/price. A worthy objective for regulators, reluctant customers, and marketers would be to move price out of the unchallenged numerator (where it now seems to live) and into its proper and equalizing role in the denominator.

Ghost markets will reappear from time to time. As long as there are headlines to be built around pollution control stories.... As long as there are alternatives to an existing technological approach.... And as long as there are entrepreneurs who can multiply two large numbers into billions of dollars of business, there will always be ghost markets to attract even the most careful venture in this legislated marketplace.

Corporate commitments will remain uncertain in support of their own environmental businesses. The attitude of internal corporate customers for these businesses may improve with time. Other opportunities, which now seem more attractive than environmental ones, may be found to have limitations of their own. However, the business cycles of environmental markets and other industries will continue to go through their more attractive and less attractive stages. Management will continue to use that "Great Exponential

Smoother in the Sky" to conclude: 1) that the last three months are a sure forerunner of the long-term future and 2) that previous periods were only deviations from the long-term situation.

A New Technical and Marketing Challenge: Hazardous Waste Management

In theory, one should be able to take the lessons learned in air pollution, water pollution, solid wastes, and other more mature environmental programs and anticipate the business problems to be faced in hazardous waste management (HWM). However, complexity seems to grow with each new problem area. Hazardous waste management will clearly be an even riskier business than its environmental predecessors. The risks will include those of technology, marketing, and regulation.

Technological risks are necessarily associated with the early stages of development of treatment and disposal approaches. The technologies still remain to be proven in commercial application, in performance, and in economics. The facilities themselves can be a source of further pollution--whether air-related, water-related, or as hazardous waste sources themselves. Technical risks are inherent in the variability of waste streams to be handled and the dependability of information on constituents. Finally, improper operation of these facilities will entail potential hazards for employees, supporting contractors, and neighbors.

Marketing risks begin with the greater complexity of this market. I used to think that the marketing of resource recovery systems (from municipal solid waste streams) was the most complex sales situation I had seen. I am already convinced that HWM marketing exceeds that complexity. The responsible hazardous waste firm will have to constantly "rub the reluctant customer's nose in it" through the questioning and verifying of the contents of the wastes received. The manifest systems required by regulators will likely be matched by the additional forms required by careful hazardous waste firms of customers. While the waste streams will come primarily from private industry, the hazardous waste firm will necessarily be dependent upon the public sector in the siting process, the permit process, and in overall reporting and regulation. Finally, given the high visibility of hazardous wastes, human emotions and local politics will play an important role.

The regulatory risks associated with HWM businesses are similar to those that I have enumerated in other environmental businesses. In this case, if enforcement is not firm and broad, waste generators will seek cheaper (albeit illegal) alternatives--despite the fines and jail sentences that may appear in the legislation. That kind of competition will quickly undermine the most carefully designed disposal venture.

To the degree that the private sector does not responsibly handle the problems of hazardous waste in the early stages of this embryonic industry, there is also the risk that society may conclude that it should be a public sector activity--even though many factors weigh against a public sector operation.

Finally, I happen to believe that accidents are going to happen--

particularly in an area of emerging technology, difficult logistics, and scientific discovery. Hence, those companies which put their good name at risk in the HWM business should plan for the time that headlines focus unkindly on them. While these companies will have chosen to serve an area of obvious public need, that same public will not be very forgiving.

The ultimate competence of an emerging hazardous waste management industry will require at least two marketing developments: 1) proven secure, and safe disposal must be made to dominate choices among technologies; and 2) customer purchasing must be made to avoid the simple selection of "lowest cost alternatives." In this life-threatening arena, we can ill afford a replay of market and regulatory processes which gave us second-grade products in municipal sewage treatment or second-grade promises in utility emission control. The hazardous waste management business will not be dependable until it is populated with first-rate companies making attractive profits and using first-rate technologies. There are already too many skeletons in the HWM business boneyard to afford avoidable or inadvertent boneyards in the future.

CLOSING REMARKS

Presiding Chairman Reznek

Let me try to sum up. I said at the beginning that I hoped you would find this conference interesting and that you would come away with some new information and some perspectives. I certainly have.

I want to go through about four impressions, two of which are not as global as the remaining ones. The first one was that I believe the sessions on foreign exchange would indicate that this industry was not as active as it should be in terms of trading technologies and finding technologies abroad.

I think the consensus was that this industry has its eye abroad and is looking for markets. It is looking for both technologies to bring in and for markets abroad.

I was also very struck by some of the expressed contrasting views of technology and innovation. Some representatives of the industry thought there were new products, new technologies, and new sciences to be applied. Others indicated that the technology was at a standstill. One paper even indicated that R&D should be evaluated as a venture--if there is a forecastable return on investment, then go ahead. There was an indication that the commitment to the R&D in the innovation process per se was not there in portions of the industry.

Let me now turn to some of the other impressions. Today we heard repeatedly that the concept away from individual specific pieces of technology has to be broadened; that the industry in the future will find ways of taking the technologies that exist now and resume using them in the fundamental production processes of our economy in order to achieve cleaner ways of producing raw materials and to find manufacturing processes for goods without incurring undesirable environmental liabilities.

One theme I picked up throughout the course of the day is the challenge for the members of the pollution control technology industry as it is configured today to begin to find ways of establishing bridges back to the basic manufacturing industries. That would give the pollution control vendor a better understanding of the industry's processes, and vendors would have a better understanding of the costs and capabilities of the separation and destruction technologies on the market.

Another theme that came up repeatedly throughout the day is the groping search for new and better ways for my agency, the EPA, to relate the public sector to pollution control problems. We devoted much time to the relationship between enforcement and regulation creating markets, and also spent considerable time on patents.

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We heard suggestions for prizes for R&D development rather than research contracting to procure that development. We heard interesting comments about underwriting money-making ventures with public involvement.

I think that I, personally, found that aspect one of the most encouraging and interesting parts of the Conference and that brings me to my last topic. Where do we go from here? And I am not sure I know the answer to that right now. But I listened very carefully to the two or three suggestions which we ought to follow up, and that we ought to put together work groups for implementing them.

One suggestion for doing this was industry by industry. Another suggestion was not as specific. But I'm going home and I am going to read over most of the transcript to try to identify ways for going forward and beginning to develop these dialogues; to try to generate ways of developing new institutional relationships.

GLOSSARY OF ACRONYMS

APC	Air pollution control
APCA	Air Pollution Control Association
APCE	Air pollution control equipment
ARP	Ammonia removal process
ASCE	American Society of Civil Engineers
BOD	Biochemical oxygen demand
BOD_5	5-day biochemical oxygen demand
BOP	Basic oxygen process
Btu	British thermal unit
CARB	California Air Resources Board
CDC	Community Development Corporation
CEQ	Council on Environmental Quality
CM	Combustion modification
CO	Carbon monoxide
CO_2	Carbon dioxide
COD	Chemical oxygen demand
CPC	Chloral plural carbons
DNA	Deoxyribonucleic acid
DOD	Department of Defense
DOE	Department of Energy
DOT	Department of Transportation
EEO	Equal Employment Opportunity
EIC	Environmental Industry Council
EPA	U.S. Environmental Protection Agency
EPRI	Electric Power Research Institute
ESP	Electrostatic precipitators
ETIP	Experimental Technology Incentives Program
FDA	Food and Drug Administration
FGD	Fuel gas desulfurization
FY	Fiscal year
GAC	Granular activated carbon
GNP	Gross National Product
GRI	Gas Research Institute
HCB	Hexachlorobenzene
HWM	Hazardous Waste Management
I/A	Innovative/alternative
I & A	Innovative and alternative
IERL	Industrial Environmental Research Laboratory
IGCI	Industrial Gas Cleaning Institute
IRS	Internal Revenue Service
LIMB	Limestone Injection into Multistage Burners
LES	Licensing Executives Society
LSA	Lignosulfonic acid
MCL	Maximum contaminant level

MESBIC	Minority Enterprise Small Business Investment Company (now 301(d) SBIC's)
MHI	Mitsubishi Heavy Industries
MLSS	Mixed liquor suspended solids
MW	Megawatt
MWe	Megawatt equivalent
NASA	National Aeronautics & Space Administration
NIOSH	National Institute for Occupational Safety & Health
NO_x	Nitrogen oxides
NPDES	National Pollutant Discharge Elimination System
NSPS	New source performance standards
O & M	Operation & maintenance
OMR	Operation, maintenance, and repair
OSHA	Occupational Safety and Health Administration
PAC	Powdered activated charcoal
PCB	Polychlorinated biphenyls
PSD	Prevention of significant deterioration
PNAs	Polynuclear aromatics
POTW	Publicly owned treatment works
BOP	Basic oxygen process
RACT	Reasonable Available Control Technology
R & D	Research & Development
RCRA	Resource Conservation & Recovery Act
ROI	Return on investment
S & E	Scientists and engineers
SBA	Small Business Administration
SBIC	Small Business Investment Company
SCR	Selective catalytic reduction
SIP	State Implementation Plans
SO_x	Sulfur oxides
SRT	Sludge retention time
TDAS	Thermal decomposition analytical system
TDU	Thermal destruction unit
TKN	Total Kjeldahl nitrogen
TNT	Trinitrotoluene
TOC	Total organic carbon
TSCA	Toxic Substances Control Act
TVA	Tennessee Valley Authority
UASB	Upflow anaerobic sludge blanket
UDRI	University of Dayton Research Institute
USDA	U.S. Department of Agriculture
VOC	Volatile organic compounds
WPCF	Water Pollution Control Federation
WWEMA	Wastewater Equipment Manufacturers